SUSTAINABLE
HUMAN ECOLOGY

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H. D. Kumar

Formerly Professor of Botany
Banaras Hindu University
Varanasi

EWP

Affiliated East-West Press Pvt Ltd
New Delhi

13, 10, 2010
14222

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Typeset by Transcriptions, Delhi 110 006
Printed at Rajkamal Electric Press, Delhi 110 033
Published by Affiliated East-West Press Private Limited
105 Nirmal Tower, 26 Barakhamba Road, New Delhi 110 001

Price: Rs 195

ISBN 81-7671-026-1

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Foreword

In this first year of a new millennium and when the human population has just topped six billion, it is timely to consider the future of humankind from a broad environmental, economic, and human-needs perspective. The closing of the twentieth century left many unsolved problems. Many persons still live below the poverty line, have nutritional or caloric deficiencies, and have access to inadequate sanitation. Water resources are already strained and could easily become more limiting than is food supply. Excessive consumption of non-renewable fuel and other resources continues to threaten the planet's climate and its ability to support life on a continuing basis. Because of all of these pressures, as well as many others, it is imperative that humanity find solutions to allow sustainable economic development without catastrophic environmental destruction.

The goal of this book is to explore the myriad interrelated factors that affect the interface of humans with their environment. The hope is that this analysis will assist planners, scientists, and others in deciding how best to mesh human aspirations with the material limitations and environmental requirements of our planet.

The factors that influence the reciprocal interactions of humans with their environment are multifaceted. It is therefore appropriate that this book contains information and opinion from diverse disciplines including economic theory, environmental science, biology, geochemistry, anthropology, sociology, management science, planning fields, environmental assessment, environmental philosophy, and humanistic thought. Although the consideration of so many approaches is daunting and probably impossible to review completely, the author has done an admirable job of gathering material from diverse sources worldwide. He summarizes and condenses that information, but honours the original authors' arguments and conclusions. The result is a balanced presentation of alternative viewpoints that will be exceptionally helpful to all those who wish to think holistically about these complex problems. This well-written monograph should prove suitable for a broad readership including (but not limited to) governmental planners, civic leaders, industrial managers, environmental scientists, social scientists, students, academics, and concerned citizens.

Dorothy L. Parker, Ph.D.
Formerly Rosebush Distinguished Professor
University of Wisconsin at Oshkosh
Currently at
Scripps Institution of Oceanography
University of California San Diego
La Jolla

Preface

Human beings depend on, and are influenced by, natural and managed systems for both basic needs and amenities. These include, for example, food, shelter, clothing, drinking water, energy, and recreation. A variety of social and economic problems arise when the availability and diversity of goods and services decline.

A number of ecological and environmental problems have emerged in the past few decades but none is more compelling than that of sustainability. This is because humankind is currently on an unsustainable path and because our activities are threatening the very life-support systems of the earth.

One of the most noteworthy hallmarks of today's complex world is a combination of overall aggregate affluence on the one hand and economic uncertainties, poverty, hunger, malnutrition, and disease on the other. Deceptive averages mask marked inequalities within and among different societies. The natural resources on which future development and progress depend so crucially are imperilled. Population growth continues to add about 85 million persons annually, mostly in the poor, underdeveloped countries. Human ecology is strongly impacted by poverty and environmental degradation.

To meet projected food demands by 2025, global average cereal yield must increase by at least 75% over the 1990 average. To establish a strong coupling between food production, poverty reduction, and environmental conservation, the increase in cereal yield will have to occur in the complex, hitherto neglected smallholder farming systems of the underdeveloped countries. For any meaningful and sustainable agricultural development, food production is a necessary but not sufficient condition for future food security—it must go hand in hand with poverty elimination and environmental protection.

Despite growing recognition of the need to move faster on the trajectory of environmentally-beneficial change, the existing legislative, institutional, and organizational structures tend to prevent and obstruct environmental policy from becoming effective catalyst for innovation in this direction. Certainly, the widely held misconception that healthier environment and economic growth are incompatible or contradictory needs to be dispelled. When properly and carefully directed, technological change can and does lead to a healthier environment as well as a more vibrant economy.

Economic globalization is already exerting multiple impacts on nature, culture, human rights, democracy, and other social, political, and environmental dimensions of human ecology with large transnational corporations acting as driving engines of globalization. As the chief rule-making body of corporate-driven economic globalization, the World Trade Organization has emerged as a bona fide global government for the 'free trade' era. Its mandate is to keep in check the regulatory powers of nations and local communities and their rights to enact laws relating to public health, food safety, environment, labour, culture, democracy, and sovereignty, while at the same time increasing the power and freedom of multinational companies to act without let or hindrance. In the context of human ecology at the edge of sustainability and at the turn of the millennium, there is need for a sharper focus on, and urgent remedial measures for addressing, the full impacts of the globalization of industrial agriculture from the point of view of farmers (especially small or marginal farmers in developing countries), consumers, food safety, world hunger, poverty, public health, and the local, regional, and global environments.

Several enlightened and discerning people have debated and written on some of the foregoing issues of current concern everywhere, and I have made a modest attempt to collate and summarize their views in this monograph. An early draft of the entire manuscript was critically read by Professor Dorothy L. Parker and I thank her sincerely for her criticism, comments, and suggestions, many of which I have incorporated.

Writing a book on such a multidisciplinary subject as human ecology requires access to a vast variety of literature in diverse fields, e.g., biology, sociology, anthropology, geography, economics, and environment. For this, I have depended, *inter alia*, on current literature supplied by the Indian National Science Academy, New Delhi, and the Institute for Scientific Cooperation, Tübingen (Germany). I thank all those who very kindly sent me reprints, newsletters, monographs, and other gray literature from time to time. Thanks are due to the Council of Scientific and Industrial Research and the Department of Science and Technology (DST), Government of India, New Delhi, for their financial support during 1994–99. I am also thankful to Dr. Parveen Farooqi (DST) for her interest in this project. I am indebted to Professor O. N. Srivastava, Director, Hydrogen Energy Centre, Banaras Hindu University (BHU), for his help, and to Dr. C. Maheshwari of the BHU Computer Centre for handling all my e-mail despatches/receptions.

Several drafts of this monograph were ably and patiently composed by Mangala Prasad Dubey.

H. D. Kumar

1

Population Growth and Resource Consumption

INTRODUCTION

In the late 1960s, there were about 3.5 billion people in the world and the global population growth rate reached an all-time high of 2.1% per year, which has since then declined by about one-third to roughly 1.4% (Population Reference Bureau, 1998). Global population size appears to have crossed the 6 billion mark in October/November 1999. By and large, life expectancies have increased in many parts of the world chiefly because of improvements in sanitation, diet, and medical care. The environmental horizon has become cleaner and transparent in some places but darkened and dirty in some others—the quality of air and water has improved in developed countries but has deteriorated in many underdeveloped countries. In many places, water use in agriculture is unsustainable and also inefficient, but happily it is being increasingly realized and appreciated that treating common resources (e.g., fisheries, water supplies, biological diversity, atmosphere, and forests) as being unlimited and free produces adverse effects on the long-term welfare of humanity.

Today the world population of nearly 6 billion is increasing by about 80 million people per year. Should growth continue at this rate (1.4%), the population size would be 12 billion in 5 decades. But this scenario appears unlikely in view of the fact that the rate of increase in population has been declining for several decades and the absolute number of people added to the world population has been falling since the early 1990s. On the other hand, in an optimistic scenario, if the annual population increase were to drop linearly from today's 80 million to zero over 5 decades, then the mean annual increase would be 40 million/year for 5 decades, and a population size of only 8 billion will be reached in the year 2050 (UN, 1996, 1998, 1998a). The United Nations demographic assessment of 1996 in a medium-variant scenario indicated a drop from the current 1.4% to 1% per annum in 2020 and to 0.4% by 2050, so that the population in 2050 would be 9.4 billion. Its latest (1998) assessment shows a steeper fall, leading to a world population of 8.9 billion in 2050 (see Alexandratos, 1999). Indeed, the fears of impending food crisis that haunted several observers until very recently have subsided following the reversal of the signals of scarcity (Alexandratos, 1999). At least over the medium term, there may be no serious global constraints to expanding world food production at a rate high enough to meet the increasing demands for food (Ingco *et al.*, 1996). According to Johnson (1999), the rate of growth of world food demand will be much slower upto 2010 than it was from 1960 to 1990. Population growth is the major factor that determines the increase in food demand whereas income growth has a smaller effect (Johnson, 1999). In the three decades (1960–90), population growth accounted for approximately three-fourths of the growth in grain use/demand. He opined that for 1990–2010, population growth may account for virtually all of the increase in global demand for grain. He anticipated a decline in grain use as well as grain prices in the next decade.

Johnson (1999) suggested that from 1990 to 2020, the production of grain will increase by 17% in the developing countries and by 9% in the developed countries. This will increase per capita production to 250 kg in developing countries and to 750 kg in the developed ones. In 2020, the developing countries will have about 82% of the world's population, up from 77% in 1990. World per capita production in 2020 would be 339 kg, representing an increase of 4% from the 1990 world per capita production (Johnson, 1999).

Most of the changes that will take place in the world in the third millennium will depend on the deeds—or misdeeds—of human beings. The millennium can add about 70–90 million people to world population every year and this additional burden will deplete the earth's natural resources further—we are already losing at least 15 million hectares of life-sustaining forests annually. Out of the 6 billion people living on the planet today, about 1.3 billion subsist on less than $1 a day, about 900 million go to bed hungry, and about 2 billion drink unsafe water.

If the current patterns of human activity continue unchanged, science and technology will not be able to prevent irreversible degradation of the environment. Science and technology have made important contributions in the past to economic growth and environmental protection. In the future, sustainable development can improve living conditions worldwide through economic development provided that local environments and the biosphere are protected, and science is mobilized to create new opportunities for human progress.

As early as 1798, T. R. Malthus had stated that "the period when the number of men surpass their means of subsistence has long since arrived". At that time, the world population was only about one billion. Now it is about 6 billion. In addition to population increase, the following are some other alarming trends:

(1) Diminishing per capita arable land and irrigation water availability.

(2) Expanding demand for food, particularly animal products, as a result of higher purchasing power and increased urbanization.

(3) Stagnation in marine fish production since 1990.

(4) Increasing environmental damage and possibilities of adverse changes in climate and sea level.

(5) Fatigue of the green revolution due to technological stagnation, leading to a decline in the per person world grain production from 415 kg in 1985 to 360 kg in 1996 (Swaminathan, 1998).

These trends have prompted some to predict that China and India may have to import over 240 million tons and 40 million tons of food grains annually by the year 2030. The entire world trade in food grains now is about 200 million tons.

Ever since the commercial exploitation of hybrid vigour in maize in the USA about 6 decades ago, great advances have occurred in the genetic enhancement of the production potential of many economic plants and farm animals including fish. The introduction of a semidwarf plant habit in wheat and rice, the exploitation of hybrid vigour in rice, and the genetic manipulation of yield and quality in several crop plants heralded the green revolution in the late sixties. High-yielding genetic strains coupled with appropriate agronomic and crop protection practices have ensured that the rate of growth in food production remains above that of population growth in many developing countries.

During the past several decades, resource use in the West continued to expand exponentially while the populations of the developing world did the same.

The West represents only 20% of the world's population but it uses 80% of the world's resources. The most crucial issue, therefore, is to curb these excessive consumption patterns in the North, and for the South to see that they avoid imitating the West in this matter. In general, there is resource and energy overconsumption in the North and excessive population growth in the South. But there are some notable exceptions to this, and there are also cases of high population growth in the North, and overconsumption in the South. The other side of the picture is that there is consumption growth and also some overconsumption in the South. Developing countries now account for half of the top 20 emitters of total carbon dioxide, including four of the top 10 (China, Brazil, India, and Indonesia). More surprising, developing countries make up 12 of the top 20 emitters of carbon dioxide per capita, including the top four. Most of these are oil producers or refiners.

General consumption too is increasing in the South. In Asia, it is growing at unprecedented rates. Per capita incomes in China grew at 8% a year during the 1980s (doubling every nine years) and in South Korea at 9%. Asia's expanding consumer class already outnumbers Europe's. So far, their consumption has mostly been limited to televisions, refrigerators, and scooters. But the list is growing much faster than at comparable stages in northern countries. This trend is environmentally disquieting and needs to be corrected in a timely manner.

Despite significant gains in improving the productivity and profitability of major cropping/farming systems, there are a few negative aspects of the world food and nutrition picture: about one in every five persons in developing countries now goes to bed hungry (food-energy deficient). Some 150 million children are underweight and 230 million are stunted. Vitamin A deficiency affects 40 million children. At least 25% of the world's population is exposed to risk of iodine deficiency. Worldwide, about 2 billion people are affected by iron deficiency. Protein deficiency is widespread in many developing countries.

Emergency feeding programmes are necessary in special circumstances but improving household access to food through poverty reduction is the only sustainable solution to the problem of endemic hunger. The Science Academies' Summit held at the M. S. Swaminathan Research Foundation in Chennai in July 1996 adopted the following definition of food security:

(1) That every individual has the physical, economic, social, and environmental access to balanced diet including the essential macro- and micronutrients, safe drinking water, sanitation, environmental hygiene, primary health care, and education.

(2) That food originates from efficient and environmentally-benign production technologies which conserve and enhance the natural resource base of crops, animal husbandry, forestry, and inland and marine fisheries.

The operational implications of this view of food and nutrition security are the following:

(1) Its physical dimensions will involve a transition from chemical- and machinery-intensive to knowledge-intensive and ecofriendly farming technologies.

(2) Its economic dimensions require the promotion of sustainable livelihoods through multiple income-earning opportunities, such as can be offered through crop-livestock-fish integration, agroprocessing, and agribusiness.

(3) Its social dimensions warrant addressing gender, class, and ethnic discrimination against marginalized sectors of society, which consequently tend to be the most nutritionally insecure.

(4) Its environmental dimensions will require due attention to soil health care, water harvesting and management, and conservation of biodiversity, as well as to sanitation, environmental hygiene, primary health care, and education (Swaminathan, 1998).

POPULATION-FOOD EQUATION

There exists a strong linkage between population, food, and nutrition. A growing population impacts adversely on both food availability and nutritional intake. As of 1988–90, at least 780 million people in the world were estimated to be chronically undernourished (Johnson, 1999). Projections indicate that this figure may decline to about 635 million in 2010 and to about 575 million in 2020. The major factor responsible for malnutrition is not inadequate supply of food but low income. Low levels of caloric intake are not the only—or even major—cause of malnutrition. Deficiencies of nutrients such as proteins, vitamins A and D, iron, iodine, and calcium contribute to malnutrition. In India, since 1948, even though production of food grains has increased by 3.5 times, cereal by 3 times, and protein by 1.5 times, yet the increase in per capita availability has been much less (UNPF, 1999). The per capita consumption has gone up only by about 27% in food grains, 35% in cereals, and about two times in edible oils. More than three-fourths of the rural populations of Assam and Maharashtra consume less than the minimum daily requirement, and about one-half of rural Gujarat and Tamil Nadu receive less than the minimum—Indian Planning Commission suggested 2400 and 2100 calories as the minimum requirement for rural and urban areas, respectively. A substantial proportion of the Indian population (both urban and rural) falls below these minimum categories. The UNPF has warned that with growing population and unsustainable agricultural practices, India is likely to face declining food productivity in the coming years. According to an estimate of UNPF, about 320 million Indian people (about one-third of its population in 1997) were considered to be food insecure as they eat less than 80% of the suggested minimum requirement.

The basic problem in India (as in many other developing nations) is not shortage of food *per se*—rather it is low incomes or the lack of purchasing power (or access to food) by many poor people who do not earn enough to be able to buy the food. India has made impressive gains in food production but has not been able to eliminate poverty. Serious failures in economic development have been the root cause of persisting poverty and food insecurity. Thus, the suggestion made in the UNPF Report that India is moving to a situation where it will not have enough food to provide adequate nutrition to its people is not really correct. India is now producing enough food—even exporting some of it; it is the access to food that has led to want in India. What the government really needs to do is to ensure equitable access to food to all its citizens.

With the advent of the Green Revolution, planting of improved crop varieties, better farm management and irrigation, and use of biocides and fertilizer combined to increase food production faster than the increase in population in certain areas. Since about 1970, in spite of rising total numbers of people, increased food production could bring down the number of undernourished people in every region of the world, except perhaps Saharan Africa. And yet, an estimated three-quarters of a billion people still suffer from undernutrition (Fedoroff and Cohen, 1999).

In recent years, there has been some optimism with regard to the population problem in view of the changing patterns in reproductive behaviour during the last three decades. In many developing countries, contraceptive use, once rare, is now widespread and the average number of births per woman (bpw) has fallen by half, from the earlier six or more to about three today. In the industrialized world, fertility has already fallen below two children per woman. The United Nations has revised downward its latest forecast of world population (see Wattenberg, 1997). Some feel that the fear of global population explosion has subsided.

At today's population of about 6 billion, we have just crossed its midpoint (UN, 1996, 1998, 1998a). After a tremendous increase by 2 billion people over the past 25 years, an increase of another 2 billion is projected to occur over the next 25 years and a further expansion to over 10 billion may occur by 2100. Nearly all of this growth will occur in the developing countries, in which four-fifths of the world's population lives. Despite the plummeting fertility rates, large increases in the populations of Africa, Asia, and Latin America are expected (Bongaarts, 1998) because (1) the average decline from six to three bpw still leaves fertility about 50% above the two-child rate needed to bring about population stabilization; with more than two surviving children per woman, every generation is larger than the preceding one, and as long as that is the case, population expansion will continue; (2) the decline in mortality continues in the face of higher standards of living, better nutrition and health services, etc.; and (3) of the population momentum, i.e., the tendency of a population to keep growing even if fertility could immediately be brought to the replacement level of 2.1 bpw with constant mortality and zero migration (Bongaarts, 1998). The reason for this growth is a young population age structure which includes probably the largest generation of women about to enter the childbearing years—women who will maintain population growth for decades, even if they each have only two children (see Table 1.1). Large increases in the population of the developing world are therefore certain to continue.

Table 1.1 Population estimates (1995) and projections to 2050 by region (in billions) (after Bongaarts, 1998)

Region	1995		2025		2050	
Africa	0.72	=5.70	1.45	=8.03	2.05	=9.37
Asia and Oceania	3.47		4.82		5.49	
Latin America	0.48		0.69		0.81	
Europe	0.73		0.70		0.64	
North America	0.30		0.37		0.38	
Developing world	4.52	=5.69	6.82	=8.04	8.20	=9.36
Developed world	1.17		1.22		1.16	

The industrialized world faces a quite different demographic future. In developed countries, the key concerns are aging and potential population decline as fertility has been below the replacement level. For the developed world, population size is projected to rise slowly until 2025 and then decline, leaving the total in 2050 about the same as today. The proportion of the population over age 65 may rise to 25% in 2050, up from 14% today.

The UN projections are all based on certain assumptions about future trends in fertility, mortality, and migration. Over the next few decades, fertility is expected to move (up or down) in both developed and developing countries to the replacement level of 2.1 bpw and may remain at that level after 2050. This assumption ensures zero population growth in the long run. But if future fertility were to level off at just half a birth above replacement, world population in 2100 would reach 17.5 billion instead of 10.4 billion; conversely, fertility at half a birth below replacement would lead to population decline in the second half of the twenty-first century to 5.6 billion in 2100 (UN, 1996, 1998, 1998a). Thus, even modest efforts to change fertility can have a substantial impact on future population size (Bongaarts, 1998).

The policy implications of current trends in reproductive behaviour differ markedly between regions. In the crowded developing world, the addition of a billion more people will adversely affect efforts to reduce poverty and achieve sustainable development. Raising education levels of girls can reduce fertility and offset momentum by delaying childbearing besides directly benefiting the quality of individual lives.

GLOBAL RESOURCES

The systems of (1) water, (2) energy, (3) environment, and (4) food and agriculture comprise the four major components of the total earth system concerned with life support (Berkes, 1989). They cover all important aspects of resources, demand, conservation, policies and technologies, and demographic impact and interplay. A fifth major area covers common science and technology which cut across the four natural resources area. The mathematical, physical, chemical, and biological sciences, which are generally applicable to the life-support systems, as well as such applied fields as mathematical modelling, artificial intelligence, information and communications technologies, mechanical engineering, and others are represented in this important area. The most complex one is the sixth major area, namely, global issues. This deals with the world as an integrated multilevel system and describes the comprehensive problem of global change with its demographic, environmental, climatic, biological, technological, economic, and social components. It also comprises the global health issue, including that of emerging and re-emerging diseases, which, according to some predictions, might soon be one of the flashpoints of human existence in the twenty-first century. The international security, in its global sense, which arises from the interaction and interplay between elements of basic natural and human-engineered resource systems, such as global environment security, energy security, and food and freshwater supply security, is now becoming critical. Education for sustainable development for the twenty-first century, together with the ethics of science, is another important theme. Systems analysis and systems engineering methods can be applied for the study of interaction and interplay between four major natural systems.

Figure 1.1 illustrates some human perspectives. Most people are less

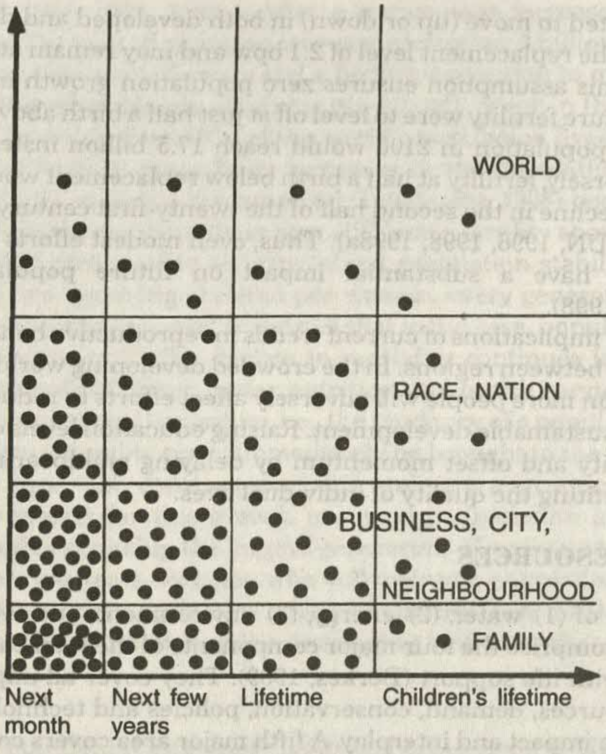

Fig. 1.1 Human perspectives (density of dots indicates strength of perspective) (after Meadows *et al.*, 1972).

concerned about future (long-term) costs and benefits than present ones.

Human activities affect the chemical and physical properties of the atmosphere. Some examples are increases in tropospheric ozone, carbon dioxide, oxides of nitrogen and sulphur, heavy metals, and UV-B radiation (wavelength 280–315 nm). Several of these changes alter the physiological status of terrestrial vegetation through either inhibition or enhancement of growth and reproduction, thereby influencing the ability of sensitive plants to compete for limited resources. Consequently, air pollution stress and mutagens may in some cases change the genetic structure of plant populations.

The deterioration of the environment became one of the grave problems of the twentieth century. We are now faced with increasing global problems—hunger and desertification, depletion of natural resources, energy scarcity, pollution, and man-made changes of climate.

Some important issues facing scientists now and in the coming few decades are the following:

(1) The increasing complexity of the global problems and the social organizations that govern human interactions and cooperation.

(2) The increasing need for sustainability in science—that is, the

need to commit resources over time to the science enterprise.

(3) The enlarging diversity of human scientific resources, which necessitates the best use of our community by deepening and broadening it.

George Bernard Shaw once said: "Science becomes dangerous only when it imagines that it has reached its goals." We are facing a huge collection of complex questions and problems. We have, for example, only recently recognized the stratospheric ozone hole and learned how our actions can make it expand or shrink. We have only partial knowledge of the basic workings of the metabolism of the earth biosphere. Understanding climate change and its effects on human health is a continuing challenge that pushes our creative limits. And we are only now beginning to know something about how the human brain works.

Strengthening human interaction is going to be vital for global peace and prosperity in the present millennium. As population growth and accompanying environmental stresses drive human migration, food and resource scarcity and outbreaks of new diseases, scientists will be called upon to help governments around the world deal with these complex issues.

Although over 130 developing countries already account for 4/5 of the world's people, they only account for 1/6 of its economic output. This pervasive condition of poverty is like a disease—not because it is contagious but rather because it devastates the stricken individuals and countries and has far-reaching implications for all the world's citizens and nations. Poverty degrades the dignity of all human beings no matter where it occurs: North, South, East or West.

This warrants a thought not only for saving our planet for future generations, but of saving the planet's current generation. Our respect for humanity's habitat must include a reverence and compassion for humanity itself. Our only hope of saving either rests in a commitment to save both. Sustainable development cannot mean sustaining poverty in those places where it exists.

The world's human population has already crossed 6 billion and most of the world's population growth and much of its economic expansion in the near future will occur in the South. Here too will exist the potential for the deepest problems of hunger, poverty, and disease, as well as for vast environmental devastation and its incumbent emergencies. The major problems facing the whole global society are human problems which come out of complex patterns of overlapping consequences. There are overlapping consequences of poverty, planetary devastation, illiteracy, aging populations, communicable diseases, energy supply, and others. Tackling these issues collectively might seem a virtually unmanageable task. But we cannot make choices among them either.

ENVIRONMENT AND POLLUTION

The work of biologists, ecotoxicologists, and meteorologists is essential for obtaining descriptive diagnoses of environmental change and the physicochemical processes involved. Physicists, chemists, and technologists work to clarify the immediate sources of environmental pollution and to design ways and means to reduce harmful emissions. Clean technology and maximum efficiency are important considerations here. The implicit assumption is that current activity patterns, flowing from social, economic, and cultural motives, need not be altered to achieve a safe and sound global environment. However, global environmental change may be too significant already and may be progressing too rapidly for technical solutions to catch up with it: the social and behavioural sciences may also be relevant in this context. Social philosophers, sociologists, economists, psychologists, and cultural anthropologists are trying to answer the question: How did society get to the point where it now endangers its own natural living conditions and harms or annihilates multitude of non-human species? Technology is undoubtedly a double-edged sword. On the one hand, it made the western welfare state possible and on the other hand, it has fed the industrial revolution with all its adverse effects on the environment.

Social scientists have generally concluded that modern industrial society is inherently expansive, that many individual benefit-seekers inevitably bring about long-term collective harm and risks, and that limiting such harm and risk requires an adaptation of society with respect to several strategic choice dilemmas. More than ever before, economic benefits now have to be weighed against environmental risks, present outcomes against future ones, and individual against collective interests (Vlek, 1993). It is now being argued that global environmental degradation is due to four basic driving forces, viz., (1) technological, (2) economic, (3) demographic, and (4) institutional. Considering these from an industrial expansion perspective, we may infer that global environmental degradation is due to (literally) overpowering technology, overproduction and overconsumption, overpopulation, and overanthropocentric (versus ecocentric) attitude inherent in society's institutions (Vlek, 1993). To stop or slow down global environmental degradation, a four-pronged environmental policy is required, namely, (1) make the technology of human enterprise sufficiently safe, (2) redirect and restrain current production and consumption patterns so that these become environmentally sustainable, (3) tackle population and management problems in relation to environmental quality, and (4) reorganize societal institutions and attitudes concerning the exploitation of natural resources.

Only one of the foregoing four policy tracks has a technological orientation. Could global environmental problems largely be solved by technical means? Technical solutions would be the easiest type, but many environmental problems are more fundamental in nature, and technology is not going to save us, either during the current environmental planning period, or even in the long term.

From a social viewpoint, the following six general strategies for influencing human behaviour may be distinguished:

(1) Providing physical or technical alternatives.
(2) Lawful regulation and enforcement.
(3) Financial-economic stimulation.
(4) Information, education, and communication.
(5) Social modelling and support.
(6) Organizational reform.

Increasing the efficiency of energy use appears to be one of the most effective ways to abate environmental impacts. The main obstacle is educating the vast numbers of individual energy consumers.

Building an environmentally-sustainable future requires a restructuring of the global economy, major shifts in human reproductive behaviour, and dramatic changes in values and lifestyles.

A proper conservation or husbandry of the land surface is also necessary for achieving sustainability (Fig. 1.2).

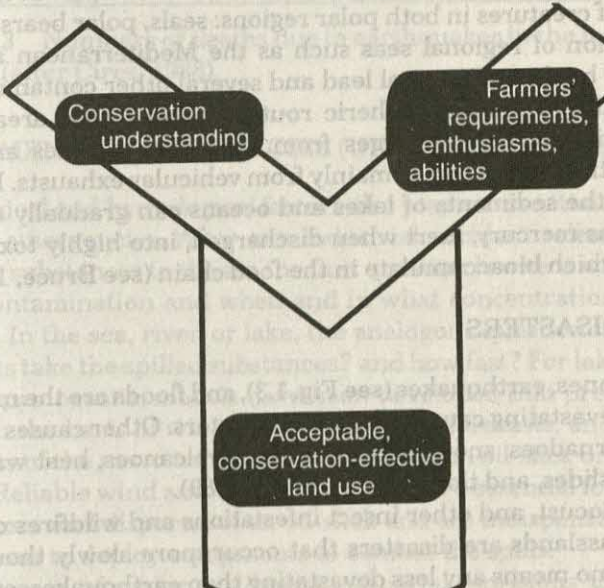
Conservation understanding
Farmers' requirements, enthusiasms, abilities
Acceptable, conservation-effective land use

Fig. 1.2 Marrying of technical and social aspects of land husbandry to achieve sustainable conservation.

MULTIMEDIA (AIR, WATER, SOIL) POLLUTION

Degradation of the atmospheric and freshwater environments occurs through unsustainable economic development. Pollutants are not confined to compartmental or geographical boundaries. Contamination of the atmosphere due to industrial activities in one country can lead to pollution of lakes in another, or of the oceans. Some pollutants from factories and municipalities discharged into rivers are transported to lakes and the sea, to rivers, or into sediments deposited in estuaries. Pesticides and fertilizers applied to soils often filter into groundwater, streams, ponds, and lakes. Pollutants in water bodies may sometimes volatilize and be transported to the atmosphere partly through foam and bubbles on the surface of water.

Atmospheric pathways are dominant inputs to the oceans for several toxic organic compounds, representing more than 80% of the total loading from all sources of PCBs (polychlorinated biphenyls), chlordane, DDTs, dieldrin, and of the HCHs (hexachlorocyclohexanes) and HCBs (hexachlorobenzenes). Sulphate and nitrate emissions from thermal power plants and industrial activities in many countries have resulted in dramatic increases in acidity of precipitation, adversely affecting lakes, soils, vegetation, and buildings, thousands of kilometres downwind of the sources. Pesticides such as DDT, dieldrin, and others occur in fatty tissue and organs of creatures in both polar regions: seals, polar bears, and penguins. Pollution of regional seas such as the Mediterranean and many coastal areas by the toxic metal lead and several other contaminants has occurred mainly from atmospheric routes though those areas receive large direct industrial discharges from shoreline factories and rivers. Lead in the atmosphere comes mainly from vehicular exhausts. Biological processes in the sediments of lakes and oceans can gradually transform metals such as mercury, inert when discharged, into highly toxic methylated forms which bioaccumulate in the food chain (see Bruce, 1992).

NATURAL DISASTERS

Tropical cyclones, earthquakes (see Fig. 1.3), and floods are the most widespread and devastating causes of natural disasters. Other causes are thunderstorms, tornadoes, snow- and ice-storms, volcanoes, heat waves, avalanches, landslides, and tidal waves (Smith, 1989).

Droughts, locust, and other insect infestations and wildfires of forests, bush, and grasslands are disasters that occur more slowly though their effects are by no means any less devastating than earthquakes, etc.; this is because their effects last longer and have a cumulative impact.

A striking fact is that most natural hazards are meteorological or hydrological, or weather-related, in some cases to geology and oceanography. These hazards become disasters only when human activities are located in the areas in which the phenomena occur.

Meteorological and hydrological information and services can aid in disaster mitigation at four stages, viz., planning, design and construction, warning systems, and immediate, post-disaster relief.

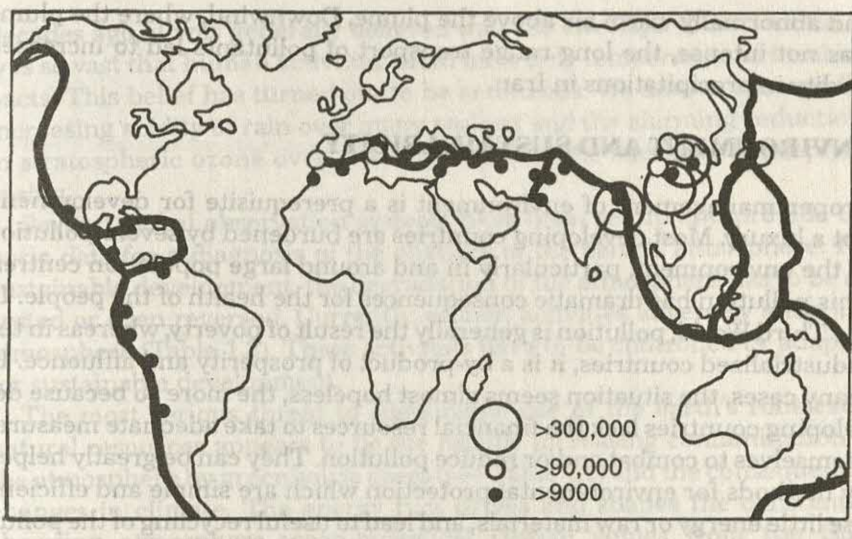

Fig. 1.3 Numbers of deaths due to earthquakes in the last 1000 years (after Cires, 1988).

ENVIRONMENTAL EMERGENCIES (UNNATURAL DISASTERS)

Meteorological and hydrological factors also play an essential role in environmental emergencies. After any industrial accident releases toxic or radioactive substances to the air, the first question is where will the winds take the contamination and when and in what concentrations will it be deposited? In the sea, river, or lake, the analogous question is where will the currents take the spilled substances? and how fast? For lakes, regional seas, and open oceans, models have been developed that predict surface currents on the basis of wind observations and forecasts, and they allow for forecasts of the movement and dispersion of an oil-slick or a light contaminant. Reliable wind and weather forecasts are essential for predicting the movement and dispersal of an oil-slick and are indispensable in guiding operations to deploy equipments to combat the spills.

Several cases of major accidental industrial emissions to the atmosphere have happened with tragic national or international effects.

The oil well fires of Kuwait lit in February 1991, following the Gulf War, caused serious impacts on local climate, health, and living conditions. At the beginning, 5–6 million barrels of crude oil and 70 million m^3 of associated gases were consumed daily. In addition to the 50,000 tons of airborne particles (smoke), of the order of 0.8–2 million tons of carbon dioxide as well as sulphur dioxide, the precursor of acid rain, oxides of nitrogen, polyaromatic hydrocarbons were emitted per day. Adverse health effects occurred due to the high concentrations of smoke particles and sulphur dioxide. Meteorological modelling of the regional effects of the heavy smoke plume revealed some cooling below the smoke in the Kuwait area, and abnormally warm air above the plume. Downwind, where the plume was not intense, the long range transport of pollutants led to increased acidity in precipitations in Iran.

ENVIRONMENT AND SUSTAINABILITY

Proper management of environment is a prerequisite for development, not a luxury. Most developing countries are burdened by severe pollution of the environment, particularly in and around large population centres. This pollution has dramatic consequences for the health of the people. In the Third World, pollution is generally the result of poverty, whereas in the industrialized countries, it is a by-product of prosperity and affluence. In many cases, the situation seems almost hopeless, the more so because developing countries lack the financial resources to take adequate measures themselves to combat and/or reduce pollution. They can be greatly helped by methods for environmental protection which are simple and efficient, use little energy or raw materials, and lead to useful recycling of the pollutants, above all for food production.

BIOTECHNOLOGY

As compared with other conventional environmental technology, the merit of biotechnology is that it makes use of microbiological mineralization processes which are part of natural cycles. Biotechnology can be used to convert organic substances into inorganic substances without any harmful by-products. Microorganisms can be used in the purification of contaminated organic compounds (removal of nitrogen, phosphate, sulphur, and heavy metals). Their use is at present limited to biological filters for cleaning waste gases. Their application in the breakdown of toxic substances in groundwater and soil and in the nitrification of liquid fertilizer is still in the research phase. For the time being, these applications are aimed at industrial pollution and are not suitable in the short term for the economies of most developing countries, which depend mainly on agriculture.

Biotechnology can also play a role in protecting the environment in developing countries. The relevant areas are the microbial purification and fermentation of liquid and solid waste and waste gases. The aerobic and anaerobic purification of waste water is an especially suitable target for biotechnology application. Biotechnology could be applied to the problems of waste disposal in large cities and drinking water supplies in developing countries.

EARTH'S ATMOSPHERE

The earth's atmosphere is an essential environment and an invaluable resource. It is essential for all life. For truly sustainable development, the nature or properties of the atmosphere must not be altered. Till only a few decades ago, it was generally believed that the envelope of air around us was so vast that human activities could have only temporary and local impacts. This belief has turned out to be erroneous. We have witnessed the increasing acidity of rain over many regions and the alarming reductions in stratospheric ozone over Antarctica during the southern hemisphere spring.

Several global observation systems have been set up and provide the basic data for a diagnosis of the changes of the earth's atmosphere. For sustainable development, the degradation of the atmosphere has to be arrested or even reversed. Currently, certain activities adversely affect the atmosphere (Table 1.2). These activities have to be controlled or adapted for sustainable development.

The most serious threat to sustainable use of the earth's renewable natural resources appears to be the rapidly increasing contamination of the atmosphere by greenhouse gases (see Table 1.2) and the consequential changes in climate. The energy that drives and shapes the constantly-changing atmosphere-ocean-biological system comes from the Sun. About one-half of the incoming sunlight energy is absorbed and reflected in the atmosphere by its clouds and dust, and the other half is absorbed and reflected by the surface of the earth. The incoming energy is balanced by the outgoing radiation at longer, infrared wavelengths from the earth and the atmosphere. Certain gases occur naturally in the atmosphere (e.g., water vapour, carbon dioxide, and methane); they radiate much of the long wavelength energy back to earth, warming the air masses near the earth's surface.

What steps can be taken to reduce impacts of climate change and to slow the rapid rate of change? Greenhouse gas emissions have to be controlled. To reduce carbon dioxide emissions and stabilize atmospheric concentrations, wasteful and unnecessary use of fossil fuels and the destruction of forests have to be curbed (Bruce, 1992).

If a 1–2% per year reduction of global CO_2 emissions were to begin now, it could result in the stabilization of atmospheric concentrations early twenty-first century. Technically feasible and cost-effective means of reducing emissions through energy efficiency and switching to renewable fuels already exist in several countries.

The reduction of the global production of CFCs (chlorofluorocarbons) and other substances that deplete the ozone layer will also effectively decrease the climatic impact of CFCs as greenhouse gases. However, it should be ensured that substitute chemicals for refrigeration and other uses are not powerful absorbers of the wavelengths that trap infrared radiation—in other words, they are not strong greenhouse gases.

Methane emissions are more difficult to control because they come from a wide range of agricultural and industrial sources and from landfill sites (dumps). However, since methane is much shorter-lived in the atmosphere than CO_2 or CFCs, even a small reduction (about 15%) of emissions would soon stabilize its atmospheric concentrations. Much of this reduc-

Table 1.2 Anthropogenic trace gases (after Graedel and Crutzen, 1989)

Gas	Major anthropogenic sources	Average residence time in atmosphere	Approximate current concentration (ppb)	Projected concentration in year 2030 (ppb)	Likely impact(s)
Carbon dioxide	Fossil fuel combustion, deforestation	100 yr	350,000	400,000 to 550,000	Greenhouse effect
Methane	Rice fields, cattle, landfills, fossil fuels	10 yr	1700	2200 to 2500	Greenhouse effect
Nitrogen oxides	Fossil fuel combustion, biomass burning	A few days	0.01 to 50 (clean to industrial regions)	0.01 to 50 (clean to industrial regions)	Acid deposition, smog
Nitrous oxide	Nitrogenous fertilizers, deforestation, biomass burning	170 yr	310	330 to 350	Greenhouse effect
Sulphur dioxide	Fossil fuel combustion, ore smelting	Several days to a few weeks	0.03 to 50 (clean to industrial regions)	0.03 to 50 (clean to industrial regions)	Acid deposition, corrosion
Chlorofluorocarbons	Aerosol sprays, refrigerants, foams	60–100 yr			Greenhouse effect, ozone depletion

tion could be obtained through reducing gas losses in the energy industry. The nitrogen oxides may be significantly reduced by the vigorous enforcing of automobile and industrial emission control standards.

It is not possible to achieve sustainable and equitable use of natural resources without substantially reducing human impacts on the global climate system.

WATER RESOURCES

Only 2% of the 1.41 billion km^3 of water on earth is freshwater of which 87% is estimated to lie in ice-caps and glaciers and the rest in deep groundwater. Only about 2000 km^3 is at any instant readily available in lakes, rivers, and shallow groundwater for numerous human uses. The fluxes of water over a period of time through the hydrological cycle are much larger than the instantaneous values since atmospheric moisture is replaced on average every 12 days and river water every 18–20 days. The annual discharge of the world's rivers is 31,000–47,000 km^3.

In lakes and reservoirs, water volumes are continually replenished by the inflowing rivers. Thus, river discharges represent the renewable water volumes available for human use. Such use presently is about double the instantaneous volume in rivers, i.e., about 3700 km^3 per year, but less than one-tenth of the annual flow averaged over the globe (Bruce, 1992).

For human uses of water on a renewable, sustainable basis, the rate of use should not exceed the minimum flows of the accessible precipitation. In many locations, these sustainable rates have already been exceeded. Human water use has grown at least 25–30 times in the past three centuries, and is now growing at between 4% and 8% per year due to rapid increases in both per capita use and the total population (see Fig. 1.4). Such high rates cannot be sustained for long in many parts of the world.

To overcome the problem of very low river flows in the dry season and

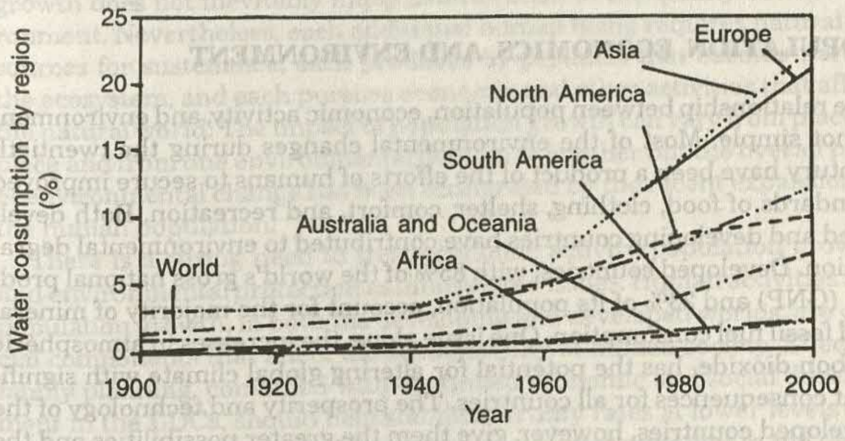

Fig. 1.4 Evolution of water consumption (after WMO, 1993).

too high flows in the rainy periods, more than 30,000 storage reservoirs have been built around the world, 75% over the last 40 years. While beneficial in many ways, such dams and reservoirs do have some detrimental effects also. They flood valuable valley lands, reduce needed annual downstream silting, and increase water-borne diseases and evaporation.

Individual human use varies greatly around the world ranging from a minimum subsistence level of 5 litres/day in some African countries to 500 litres/day in North America. To sustain a reasonable quality of life requires about 70–100 litres/day per person. Most household uses of water are not 'consumptive'. Use is consumptive when water does not return to a watercourse but mainly evaporates into the atmosphere. The major consumptive use is for irrigation, with smaller fractions applying to industrial and domestic uses. Most domestic and industrial water withdrawals are returned to the water bodies as waste water often containing pollutants.

Asia constitutes the largest area under irrigation in the world. There about 1300 km^3 of its drawn water irrigates 140 million hectares, mostly in China, India, and Pakistan. In contrast, South America irrigates only 8.5 million hectares with 70 km^3 of water.

At present, water pollution kills some 25 million people in developing countries each year, 60% of them children. Half the world's leading diseases are transmitted by or through aquatic vectors. Polluted water is an ideal breeding ground for pathogens and carrier of several diseases.

Reliable estimates of hydrological parameters such as stream flow, water-levels, precipitation, and evaporation are essential for assessing groundwater recharge rates and optimum irrigation schedules. Surprisingly, global estimation of the precipitation component of the hydrologic cycle is one of the least well-known, especially over the large part of the earth covered by oceans (see Kumar and Häder, 1999). Also, reliable predictions of daily river flow and seasonal water supply are valuable for management and allocation of available water resources to competing needs.

POPULATION, ECONOMICS, AND ENVIRONMENT

The relationship between population, economic activity, and environment is not simple. Most of the environmental changes during the twentieth century have been a product of the efforts of humans to secure improved standards of food, clothing, shelter, comfort, and recreation. Both developed and developing countries have contributed to environmental degradation. Developed countries, with 85% of the world's gross national product (GNP) and 23% of its population, account for the majority of mineral and fossil fuel consumption. One issue alone, the increases in atmospheric carbon dioxide, has the potential for altering global climate with significant consequences for all countries. The prosperity and technology of the developed countries, however, give them the greater possibilities and the greater responsibility for addressing environmental problems.

In the developing countries, the resource consumption per capita is lower, but the rapidly-growing population and the pressure to develop their economies are leading to substantial and increasing damage to the local environment. This damage comes by direct pollution from energy use and other industrial activities, as well as by activities such as clearing forests and inappropriate agricultural practices.

Scientific and technological progress, such as in agriculture, has been able to overcome many pessimistic predictions about resource constraints affecting human welfare. Nevertheless, the present patterns of human activity, accentuated by population growth, invite a serious reconsideration of the idea of ignoring these threats to our planet. Unrestrained resource consumption for energy production and other uses, especially if the developing world strives to achieve living standards based on the same levels of consumption as the developed world, could lead to catastrophic outcomes for the global environment.

Some of the environmental changes may produce irreversible damage to the earth's capacity to sustain life. Many species have already vanished and many more are awaiting the same fate. Man's own prospects for achieving satisfactory living standards are threatened by environmental deterioration, especially in the poorest countries where economic activities are most heavily dependent on the quality of natural resources.

If they are forced to deal with their environmental and resource problems alone, the LDCs (least developed countries) face overwhelming challenges. They generate only 15% of the world's GNP, and have a net cash outflow of tens of billions of dollars per year. Over 1 billion people live in poverty, and 600 million on the edge of starvation. And the LDCs have only 6–7% of the world's active scientists and engineers, a situation that makes it very difficult for them to participate fully in global or regional schemes to manage their own environment.

In places where resources are administered effectively, population growth does not inevitably imply deterioration in the quality of the environment. Nevertheless, each additional human being requires natural resources for sustenance, each produces by-products that become part of the ecosystem, and each pursues economic and other activities that affect the natural world. The impact of population growth can vary from place to place and from one environmental domain to another but the overall pace of environmental change has been accelerated by the recent expansion of the human population.

There is a strong need to treat economic activity, population growth, and environmental protection as interrelated issues. Human activities and population growth, in both the developing and developed worlds, are crucial components that affect the sustainability of human society. Effective family planning, combined with continued economic and social development in the LDCs, should help stabilize fertility rates at lower levels and reduce stresses to the global environment. Greater attention in the developed countries to conservation, recycling, substitution, and efficient use of energy and a concerted programme to start mitigating further build-up of greenhouse gases will go a long way to help scale down the threat to the global environment.

Unlike many other steps that could be taken to cut down the rate of environmental changes, reductions in rates of population growth can be accomplished through voluntary measures. The excessive population growth in the developing world could be checked by providing people with the means to control their own fertility. Family planning programmes can very likely reduce rates of population growth and so arrest environmental degradation. Furthermore, unlike many other potential interventions which are typically specific to a particular problem, a reduction in the rate of population growth would affect many dimensions of environmental change. Its importance is underestimated if attention is focused on one problem at a time.

Some of the aspects or areas to which scientific research can contribute include development of new generations of safe, easy to use, and effective contraceptive agents and devices; development of environmentally-benign alternative energy sources; improvements in agricultural production and food processing; further research in plant and animal genetic varieties; further research in biotechnology relating to plants, animals, and preservation of the environment; and improvements in public health, especially through development of effective drugs and vaccines for malaria, hepatitis, AIDS, and other infectious diseases causing immense human burdens. Also needed is research on subjects such as improved land use practices to prevent ecological degradation, loss of topsoil, and desertification of grasslands; better institutional measures to protect watersheds and groundwater; new technologies for waste disposal, environmental remediation, and pollution control; new materials that reduce pollution and the use of hazardous substances during their life cycle; and more effective regulatory tools that use market forces to protect the environment.

Much greater attention needs to be given to understanding the nature and dimension of the world's biodiversity. Although we depend directly on biodiversity for sustainable productivity, we cannot even reliably estimate the numbers of species of organisms—plants, animals, and microorganisms. We do know, however, that the current rate of reduction in biodiversity is unparalleled over the past 65 million years. The loss of biodiversity is one of the fastest moving aspects of global change, is irreversible, and has serious consequences for the human prospect in the future.

Scientific research and technological innovation can undoubtedly mitigate the problems of resource and environmental stresses and facilitate a less destructive adaptation of growing population to its environment. Yet, it does not seem advisable to rely on science and technology alone to solve problems created by rapid population growth, wasteful resource consumption, and harmful human practices. Science and technology have an especially important role to play in developing countries in helping them to manage their resources effectively and to participate fully in worldwide initiatives for common benefit. Capabilities in science and technology must be strengthened in LDCs as a matter of urgency through joint initiatives from the developed and developing worlds. But science and technology alone are not enough. Global policies are urgently needed to promote more rapid economic development throughout the world, more environmentally-benign patterns of human activity, and a more rapid stabilization of world population. The future of the planet earth hangs in the balance. Sustainable development can be achieved, but only if irreversible degradation of the environment can be halted in time. The next few decades will be crucial in this context.

The general relationship between stock of some crop and sustainable yield is illustrated in Fig. 1.5.

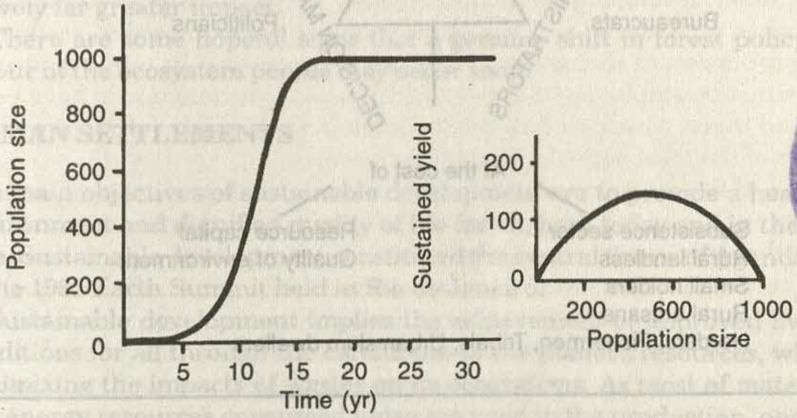

Fig. 1.5 Relationship between population size (e.g., crop) and sustainable yield (right, inset) for the logistic curve (shown on left). Here, maximum sustainable yield is obtained when population stock is harvested to maintain it at one-half of its carrying capacity. (After Caughley, 1977.)

STATE SUBSIDIES

Large state-sponsored subsidies have created an iron triangle of components of Indian society benefiting from, administering, and deciding upon resource subsidies. These components are forcing the country into a pattern of exhaustive resource use at the expense of the environment and the majority of the people (Fig. 1.6).

According to Gadgil (1991), the root cause of the erosion of India's forest cover lies in the way the components of this iron triangle operate. Receiving resources at throw-away prices, they have little interest in their sustainable use. Renewable resources with high prices compared to harvesting and processing costs, would tend to be overexploited. Adequate levels of taxation to curb this tendency are called for, but exactly the opposite has

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happened in India, with resources already susceptible to overexploitation pushed further in that direction through state-sponsored subsidies!

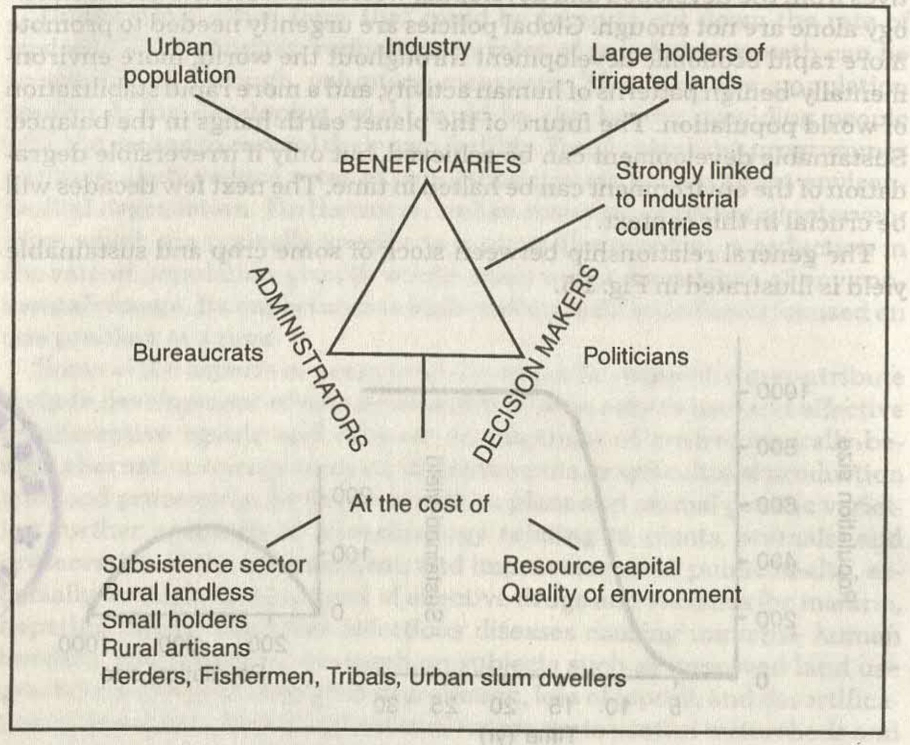


Fig. 1.6 Iron triangle governing resource use patterns in India (after Gadgil, 1991).

This exhaustive pattern of resource use obviously has a major impact on the people of that ecosystem, whose enormous population is distributed all over the country. Indeed, except for a few uninhabited islands of the Andaman and Nicobar chain, there is hardly any forest area that is not used somehow by local people. Ecosystem people have thus been forced to meet their growing biomass needs from a shrinking resource base in an unregulated manner. This has resulted in the degradation of large areas of lands that were forests once. It is only the ecosystem people who have a genuine stake in the well-being of the country's vegetation cover. They depend directly on the vegetation. It is they who suffer the most if this vegetation is destroyed and, unlike the omnivores, they have no other options (Gadgil, 1991). There is need to ensure that the real interests of the ecosystem people are protected. Their demands on biomass are manifold, and they need a great diversity of species to meet them. In some districts, as many as fifty different species of plants are used as a source of material for making brooms, baskets, implements, furniture, and decorative articles. Fruits of about a dozen species are regularly consumed and the leaves of another dozen species are used as fodder. Up to twenty species provide non-wood products of commercial value. And hundreds of plant species are used for medicinal purposes.

All over India, there is a great variety of herbs, shrubs, climbers, and trees in whose survival and availability the local people have a genuine stake. There are traditions of using these species without destroying the structure of the forest community itself. The primary interest of people is in non-wood products; even the firewood is extracted as small branches and twigs only. Trees are felled only occasionally to meet subsistence needs, unless of course the vegetation is highly degraded. Tree-felling is invariably prompted by the commercial demands of omnivores, not by subsistence demands of ecosystem people. That is why the seemingly smaller quantitative demands for biomass by the omnivores have a qualitatively far greater impact.

There are some hopeful signs that a genuine shift in forest policy in favour of the ecosystem people may occur soon.

HUMAN SETTLEMENTS

The main objectives of sustainable development are to provide a healthy environment and dignified quality of life for all, both today and in the future. Sustainable development constituted the central theme of Agenda 21 of the 1992 Earth Summit held in Rio de Janeiro.

Sustainable development implies the achievement of improved living conditions for all through the careful use of the planet's resources, while minimizing the impacts of wastes on its ecosystems. As most of material and energy resources consumed today are used in the production, operation, and maintenance of human settlements, the theme of sustainable human settlements understandably received much attention within Agenda 21.

Unfortunately, the reality is that despite the many positive commitments agreed upon within Agenda 21, the policies now being applied by governments throughout the world in support of free markets and economic globalization are severely and negatively affecting the follow-up on those agreements (Flores, 1994).

Long before Agenda 21, development of human settlements was being practised by the world's communities; people have survived by making great efforts and self-sacrifices to create new paths to development through creativity, resourcefulness, and inventiveness.

In pursuance of the policies being implemented in support of the free market, some governments have abandoned direct attention to urban services, housing, and other supports. While Agenda 21 specifically recognizes the right to adequate housing as a basic human right, instances of nations cancelling that right are growing. This has sometimes resulted in increased environmental degradation and growing poverty. The lengthening distance between the rich and the poor accelerates in the North and in the South. And as poverty increases, a new category of the excluded is formed: the leftover, the throwaway, the hopeless.

Thus, the human settlements problem today is not only the fact that 1 billion people continue to live in precarious housing conditions or without basic shelter, but also that progress has been reversed in many critical areas (Flores, 1994).

ENVIRONMENTAL HEALTH

Human settlements—in the broad context of shelter, related amenities, and neighbourhood—represent the environment most relevant to human beings, especially women and children who are the most intensive users of the dwelling place.

In most developing countries, the last 40 years have brought rapid growth in total as well as urban populations. In many countries, a substantial proportion of this growth has been concentrated in one city as new investments, employment opportunities, and government jobs have been located there. Already cities in the developing world are absorbing two-thirds of the total national population increase.

One of the most important consequences of such phenomenal population growth, which has implications for human environmental health, has been the chaotic spatial and physical growth of cities. It is now common to find residential areas next to industrial sites, or industries enveloped by housing estates, with all the potential risks to environmental health. Accompanying this trend in urban human settlements development has been the rapid growth of settlements housing the poor; such settlements grow much more rapidly than the more formal parts of the city. Most of the urban poor live in overcrowded conditions in tenements, cheap boarding houses, squatter settlements or illegal slums. In most cities in developing countries, between a third and two-thirds of all inhabitants live in illegal settlements with inadequate or no provision of infrastructure and services.

The classification given in Table 1.3 provides a systematic overview of human settlements-related health determinants and their implications for community health.

ROLE OF URBAN OASES AND FORESTS IN URBAN PLANNING

Trees play an important role in the urban canopy energy balance by blocking, and thus reducing, the incoming net radiant flux by day, and trapping the night time outgoing long-wave radiation. The impact of tree cover is stronger than of building cover. An irrigated green park surrounded by trees creates stable atmospheric conditions by day, due to blockage of solar radiant fluxes by leaves and due to the high soil moisture content. A daytime temperature inversion forms from the ground. At night, dew formation releases the latent heat and reduces soil vertical temperature gra-

Table 1.3 Human settlements and environmental health

Environmental health determinants	Disease group		
	Communicable diseases	Non-communicable diseases*	Mental illness and psychological disorders
Building-related	Building-related insect vector diseases Overcrowding-related diseases	Dust- smoke- damp-induced diseases Insect-related infections Poisoning	Psychic stress, neurosis, psychosis
Water supply-related	Faeco-oral (water-borne and water-washed) diseases Non-faeco-oral water-washed diseases Water-based diseases Water-related insect vector diseases	Water-based diseases Water-washed carcinomas	None
Sanitation-related	Non-bacterial faeco-oral diseases Bacterial faeco-oral diseases Geohelminthiases Toenlases Water-based helminthiases Excreta-related insect vector diseases	None	None

Table 1.3 Human settlements and environmental health (cont.)

Environmental health determinants	Disease group		
	Communicable diseases	Non-communicable diseases*	Mental illness and psychological disorders
Refuse-related	Refuse-related insect vector diseases Refuse-related rodent vector diseases	Poisoning Accidents	Psychic stress, neurosis, psychosis
Food-related	Food-borne diseases	Food-borne diseases	Typhoid psychosis
Industry-related	None	Disease due to industrial pollutants and toxicants Poisoning Accidents	Psychiatric organic disorders due to industrial toxicants Psychic stress, neurosis, psychosis
Natural and social environment-related	Drainage- and flood-related diseases	Diseases due to animal faeces Diseases due to animal bites	Psychic stress, neurosis, psychosis Violence (mugging, rape, homicide) Delinquency and vandalism Drug and alcohol abuse

*Defined, for the present purpose, as diseases for which person-to-person transmission does not occur or is epidemiologically unimportant.

dients, with a decrease of temperature from the ground to a small depth.

URBAN PLANNING

The concept of sustainable management applies both to rural and natural resources and also urban areas. In fact, sustainable management of urban areas is seen internationally as one of the keys to achieving sustainable development.

Natural and physical resources include energy and all structures such as any building, equipment, device, and other facility made by people and which is fixed to land.

Urban centres use, or affect, a considerable part of a country's natural and physical resources because population, industry, transport, and communications are concentrated in these places. Sustainable resource use will, therefore, have to be carefully considered in formulating urban policies so that attention is paid to areas of choice as far as ecological and amenity values are concerned. Urban centres also contain important natural resources which should not be overlooked. Cities are a major source of pollutants which can affect the natural resources far outside their immediate environs.

OBJECTIVES FOR SUSTAINABLE METROPOLITAN AREAS

In metropolitan areas, the interactions between land, water, and air have both beneficial and adverse effects. Avoiding, remedying or mitigating the adverse effects of these interactions requires objectives grounded on sustainability principles. With such a complex thing as the city, it is necessary to think in terms of objectives in several layers or a hierarchy. First-level objectives are:

(1) To maximize people's accessibility to each other and those places which provide for their needs and wants.

(2) To minimize expenditure of effort as measured in terms of energy, time, and cost.

(3) To maximize health and safety through protection from such elements as noise, heat, and human aggression.

(4) To maximize opportunities to use, while protecting, natural and heritage areas.

(5) To strive for an optimum synthesis of the objectives stated in (1)–(4).

Some of the policies to achieve these objectives include:

(1) Containing the outward expansion of the city by encouraging medium and, where appropriate, higher density development designed to achieve positive environmental effects, such as enhancing community interaction, improving living environments for the aging population, maintaining viable trade catchments for existing commercial centres, and re-

ducing the need for commuting by private cars.

(2) Encouraging the judicious use of land with high quality soils, including ecologically-sustainable farming practices, while ensuring that no inappropriate use of these lands occurs (see Fig. 1.7).

(3) Locating new development to maximize use of existing infrastructure.

(4) Identifying and promoting positive community attitudes towards sensitive ecological areas so as to avoid adverse effects on these areas.

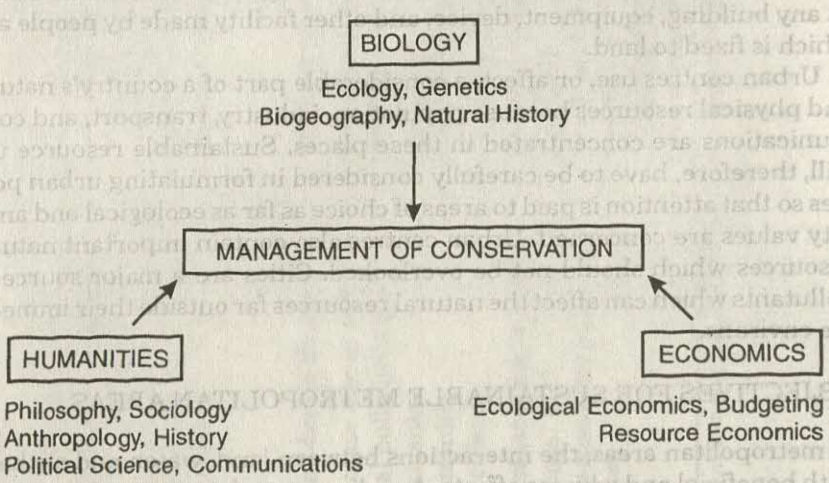

BIOLOGY
Ecology, Genetics
Biogeography, Natural History
MANAGEMENT OF CONSERVATION
HUMANITIES
Philosophy, Sociology
Anthropology, History
Political Science, Communications
ECONOMICS
Ecological Economics, Budgeting
Resource Economics

Fig. 1.7 Conservation management as a complex mix of several concerns.

ANTHROPIC PRINCIPLE

The world over, activities and misdeeds of human beings have directly and indirectly spoiled the self-sustaining and natural regenerative capacity of some ecological systems (see Hecht and Cockburn, 1990), leading to a variety of grave problems that require direct management, such as the following:

(1) As protected areas are usually too small to support all of the species they might once have held, intervention management can help maintain populations at viable levels. For the same reason, protected areas often lack the normal patterns of disturbance that generate important processes of resource diversity. Management can simulate those disturbances.

(2) Protected areas are often so fragmented and isolated that natural migration fails to balance local extinctions. Managers can help to translocate individuals between management areas.

(3) Protected areas are typically surrounded by hostile anthropogenic environments that harbour invasive species such as weeds and generalist predators, also degrading processes (siltation and pollution).

Proper management can help minimize or remove such influences.

According to the anthropic principle, physical laws can be explained by the fact that they have given rise to intelligent human beings (Smith and Szathmary, 1996). This principle may have possibly contributed something to the formulation of other, potentially more useful, approaches to the problem of the likelihood of habitable worlds (see Barrow and Tipler, 1986).

A weak form of the anthropic principle merely states that certain universes, with unfortunate lists of physical constants, would not be observable by us, simply because we would not be there. The weak principle merely acknowledges a peculiar situation. In contrast, the strong principle (see Barrow and Tipler, 1986; Smith and Szathmary, 1996) states that the universe must have those properties that allow life to develop in it at some stage of its life history. The simplest interpretation may be that the universe was designed by God who intended that intelligent life should evolve. This interpretation lies outside science. Within science, there are two possibilities. First, there is only one universe possible on logical grounds, and the list of constants follows from a (so far unavailable) theory of everything. Second, there may indeed be several possible alternative universes.

Evolutionary biology attempts to explain past events in terms of the theory of natural selection. To explain a particular event, say, the origin of the eukaryotes, is to show that, given plausible initial conditions, the event, if not inevitable, was at least reasonably likely. The explanation should also be supported by evidence: the symbiotic theory of the origin of the eukaryotes is supported by the presence in mitochondria of DNA and a bacteria-like translating machinery.

There are some difficulties. Models of natural selection in biology assume that the total population size is limited—an assumption true of real populations, except for short periods of time. A population of causally isolated universes would not be limited.

SUSTAINABLE CONSUMPTION

There is a great need for industrialized countries to find ways and means of moving towards more sustainable patterns of consumption, and identifying the issues relevant to mobilizing changes towards sustainable consumption among governments, UN, industry, research, voluntary organizations, and media.

Further, a focus is needed on the concept of the company and how the issue of sustainability is changing its identity, structure, and societal role. The involvement of labour and local communities in the development of sustainability also deserves to be considered.

TRICKLE-DOWN EFFECT

The attempt to maintain and to raise social status is one of the primary driving forces underlying the continuing increase in consumption which in turn generates some environmental problems. Can more or less spontaneous counter-forces be identified which have some restraining effect on the increase in consumption? Under what conditions do people voluntarily limit their consumption? Does restraint occur in relation to environmentally-relevant behaviour, and does status play a role in making it more widespread?

Much published sociological research has confirmed a clear relationship between power, wealth, and respect on the one hand, and the amount of consumption on the other. In many cases, a mechanism has been indicated, which the American anthropologist Lloyd A. Fallers termed the "trickle-down effect". What this amounts to is that patterns of consumption and consumer goods which were initially reserved exclusively for the members of socially-advantaged groups become distributed through wider layers of the population (Goudsblom and Aarts, 1994). This has the effect of arousing in them a self-perception of social advancement. In this way, tangible components of the lifestyle, such as holidays, aeroplane trips, cars, and eating meat every day, trickle (or sink) down, as do less tangible elements, such as calculating behaviour and sensitivity to art and to nature (Goudsblom and Aarts, 1994).

High status, however, is not necessarily always accompanied by maximal consumption. History abounds in examples where the members of privileged groups placed limitations on each other and on themselves. In some respects, it was precisely they who were subjected to a strong social compulsion to self-control. In situations of social competition between groups with economic power on the one hand, and culturally-rich groups on the other, the latter frequently tend to differentiate themselves by consumption that bears witness to self-control, tact, and good taste. As consumer goods become more widespread, their status-conferring character often relegates into the background and it is then precisely economizing which often becomes prestigious. The better-off social classes are distinguished from the weaker sections by a smaller percentage of smokers and a more healthy dietary pattern.

Studies of the evolution of smoking behaviour since the Second World War have shown that status has played a conspicuous role in the suppression of smoking in our society. Non-smoking spreads downwards through the social ladder of the population. Just as with smoking, environmentally-relevant behaviour is also voluntary, but without the social pressure.

In some environmentally-conscious countries, such as the Netherlands, there has been a healthy trend of a growing social esteem for all sorts of restraint. The prestige of environmentally-friendly restraint is increasing under the influence of extensive attention in the media and the efforts of government and industry. Further, restraint in consumption appears to be interrelated in different areas, such as automobile use, energy, meat consumption, and smoking. In fact, the preference for moderation can be traced back to a general striving for self-control, sense of responsibility, and quality.

CLIMATE VARIABILITY AND FOOD VULNERABILITY

Climate variability is the main source of fluctuations in global food production, particularly in the semiarid tropical countries of the developing world. Throughout history, extremes of heat and cold, droughts and floods have wreaked havoc on the agricultural systems that we depend on for food. Often in conjunction with other factors, climate variability contributes to vulnerability to economic loss, hunger, famine, and dislocation. Understanding of climate variability aspects is necessary for formulating more sustainable policies and strategies to promote food production.

Several critical issues such as the rapid growth in the world population, which is accompanied by enormous pressure on natural resources, especially in the developing countries, warrant early implementation of strategies to cope with climatic variability so that we can minimize its influence on food production. Two major time scales of climatic variability and changes are pertinent in this context. These are:

(1) Short-term natural disasters (e.g., cyclones, hurricanes, typhoons, effects of volcanic eruptions, and large-scale flooding).

(2) Inter- and intraannual variability. Many instances of the devastating effects of interannual variability of rainfall on crop yields and national economies are known.

FOOD SUPPLY AND DEMAND

The per capita food supply in the developing countries of 2520 calories per day is 25% below that of the developed countries (Sivakumar, 1998). One out of every five or six persons in developing countries lacks access to adequate food.

The world added 1.15 billion tons of food grains between 1950 and 1990, but if the present trends continue, the next four decades will add only about 370 million tons. With population growing by nearly 90 million per year, the amount of grain produced per person is decreasing.

It is expected that in developing countries cereal demand will increase by about 80% between 1990 and 2020 (Fig. 1.8) whereas the world as a whole will increase its cereal demand by about 55%. The projected demand for cereals, meat, and roots and tubers varies significantly among different developing countries. Net cereal imports by developing countries are likely to increase from 90 million tons in 1990 to 190 million tons by 2020.

A specific climatic event, e.g., prolonged hot, dry season, can have a strong effect on commodity prices.

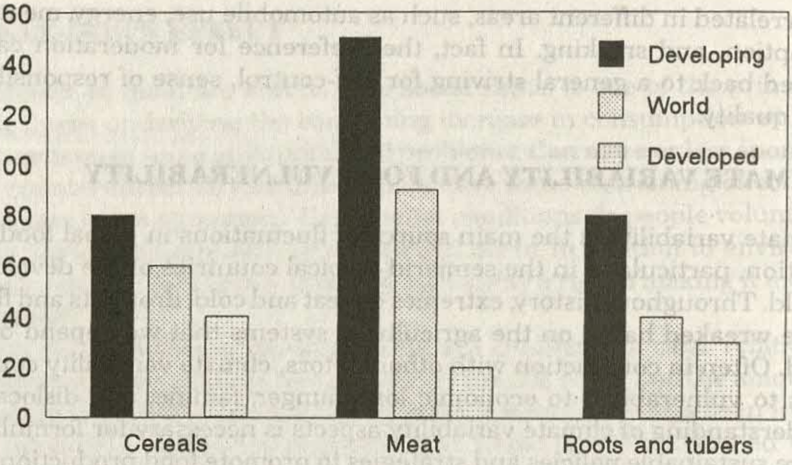


Fig. 1.8 Per cent increase in total food demand, 1990–2020 (after Sivakumar, 1998).

EFFECT OF CLIMATE VARIABILITY ON AGRICULTURE

Kates (1985) classified various approaches to the study of the effect of climatic variability on agriculture into two main categories: impact approaches and interaction approaches. An impact approach is based on the assumption of direct cause and effect, where a climatic event such as drought operating on agriculture may have some impact. The interaction approach is based on two assumptions, namely, (1) a particular climatic event is merely one of the many processes (both societal and environmental) that may affect agriculture, and (2) the impact cannot be separated from agriculture, but it is one of the many constituent processes within it (Sivakumar, 1998).

CLIMATIC VULNERABILITY OF MAJOR FOOD CROPS

Though climate variability affects all principal food crops, the degree of vulnerability of a given crop varies, depending on the nature of climatic variability, the crop growth stage at which it occurs, and the location where the crop is grown. The impact of short-term climatic variations is extremely important in marginal areas.

About 300 million farmers grow rice in a wide range of ecosystems and water regimes: irrigated, upland, rain-fed, lowland, deep water, and coastal wetlands. Drought greatly affects the growth of upland rice. Extreme temperatures also affect rice growth and yield. The critical low and high temperatures (<20°C and >30°C) vary among the growth stages.

Wheat is grown under temperature extremes ranging from –4°C in winter in parts of Canada to +40°C during grain filling (maturing) in some low-altitude regions. In South Australia, 70–80% of the variation of wheat yield over 296 locations over the years 1896–1941 could be accounted for by variations in seasonal rainfall.

In China, maize is cultivated along the seacoast in the East to the arid highlands in the West. In the higher latitudes, cold waves cause heavy damage to maize.

Some 79% of the world's sorghum and pearl millet area (about 70 million hectares) is situated in the less developed countries of the semiarid tropics of Asia and sub-Saharan Africa and are primarily rain-fed.

Meteorology plays a very important role in designing effective strategies for coping with climatic variability. Even though climate variability is a natural phenomenon in semiarid regions, much can be done to reduce its adverse impacts on the environment. A few aspects that deserve attention in this context are the following:

(1) Strategic planning studies for assessment of natural resources to enable long-term development planning or crop diversification.

(2) Monitoring of short-term variations in crop growth and development due to intraseasonal variations in weather so as to facilitate operational decision-making during the growing season.

(3) Seasonal to interannual prediction to help counter climate-induced variability, especially in the tropical regions, and help agriculture adapt to changing conditions (Sivakumar, 1998).

THRUST AREAS

In the march towards development, poverty alleviation, and environmental protection, three thrust areas in need of research are (1) biodiversity and multispecies production systems, (2) ecosystem state and function, and (3) water resources (Fig. 1.9).

For biodiversity and multispecies production systems, priority should be given to the following issues:

(1) Assessment of the qualitative and quantitative stocks of and changes in the natural resource base using local communities. This includes assessment of indigenous knowledge and linkages with modern techniques such as GIS (geographic information systems).

(2) Dynamics of different ecological and economic forms of land use in an area.

(3) Impacts of physical interventions and government policies on resource use and livelihoods.

For ecosystem state and function, the key questions may be the following:

(1) The effects of land use changes on vegetation structure and their impacts on the livelihoods of (local) people. What are the long-term effects of drought?

(2) The relationship if any between land tenure type and environmental degradation. What are the indicators of environmental change or land degradation?

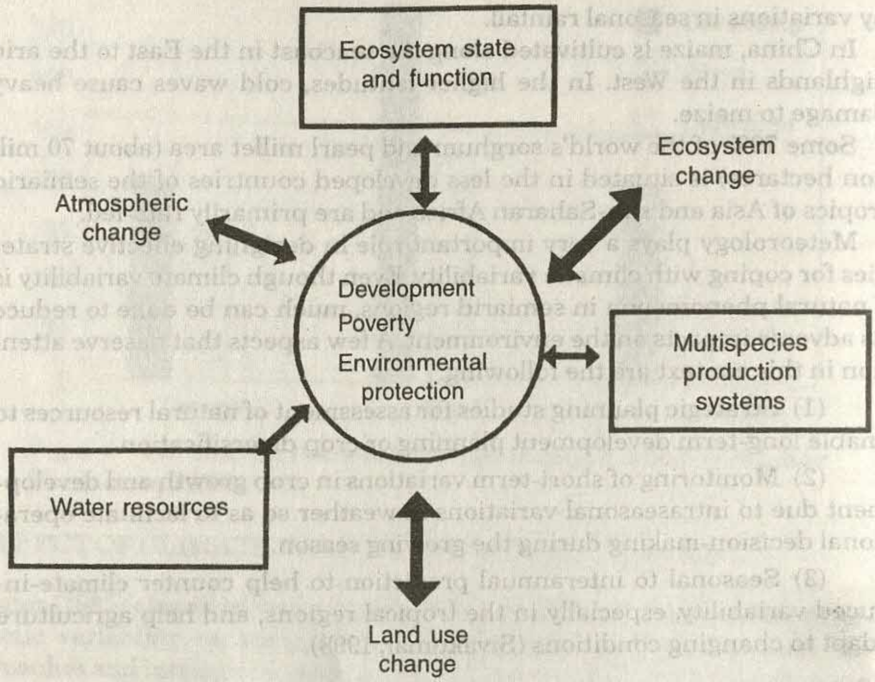


Fig. 1.9 Conceptual framework for sustainable natural management in an area.

There is also a need to understand ecosystem functioning before indicators of change could be identified which entails understanding the relationships between herbivory, phosphorus, nitrogen, and carbon cycles, and plant productivity.

As regards water and climate, the supply of and demand for water are the major issues that need to be addressed. How much of surface and groundwater is available and what is the current and future demand for it? Some supply side questions are:

(1) What is the relationship between fresh and saline groundwater?

(2) How will climate change influence hydrological processes in the long term?

(3) How may development upstream affect supply and demand downstream?

(4) How will changes in climate influence the dynamics of occurrence of vegetation and groundwater?

(5) How will water scarcity affect the distribution to various stakeholders?

(6) What socio-economic factors affect water demand and quality?

CORPORATE ENVIRONMENTAL MANAGEMENT

The advent of globalization has changed the speed with which ideas, products, and services move around the world and the way companies do business. This has raised the question of how the environment would fare under globalization, and how firms might use environmental management strategies to maintain or improve their competitiveness. A new sense of corporate environmental responsibility has arisen. Trade liberalization has made goods, services, and capital flow across traditional geopolitical borders increasingly meaningless and irrelevant. Traditional approaches to managing the environment have become obsolete. Corporate environmentalism has acquired a new face.

The following trends appear to be particularly important for facilitating corporate environmental management and business responsibility for sustainable development (Flaherty and Rappaport, 1997):

(1) As companies seek greater uniformity in process, production, and product standards, geographic location is becoming less and less important, but socio-economic and environmental distinctions are becoming more important.

(2) The produce-based manufacturing is shifting to service-based commerce in some industrial sectors.

(3) With increasing investment flows in developing countries—and increasing decentralization of corporate authority within transnational firms—firms based in the Third World are playing a more important role in the development and production of goods and services; in this they receive support from Third World institutions.

(4) Globalization is broadening the range of any particular company's stakeholders.

(5) More and more collaborative approaches (both national and international) to resolving environmental problems are emerging.

The ability of many companies to work efficiently depends on their accountability and status or reputation among their shareholders. Companies are also recognizing that doing a good job on the environment cannot be separated from social and community responsibility issues.

Some companies are actively incorporating a proper consideration of environmental concerns in all or most of their decisions, so as to respond to new market opportunities and reconceptualize their core businesses. As reputed companies advance towards effective sustainable development, the issues of environment, economics, and social responsibility are becoming blurred.

On the other hand, there are several companies which have not adopted any serious environmental management programmes. While opportunities abound for improving corporate environmental management in many developing nations, there are also barriers to sustainable development. Some large corporations have to be persuaded or even forced to change.

These corporations duck and hedge, advocate gradualist solutions, and attempt to derive maximum publicity from fragmentary, piecemeal changes in environmental management systems. According to Welford (1997), business has generally tended to ignore the root causes of the current environmental crises, viz., consumption patterns, materialism, and unsustainable growth. Welford feels that some large corporations claim to contribute to sustainable development but give scant attention to crucial social and ethical dimensions inherent in the concept. Doubtless, firms do increasingly acknowledge the need for a stakeholder approach, and even include this in their environmental planning, but many of them actually fail to address the negative social impacts of their activities.

Any effective sustainable production systems and procedures must go in for systems that make fewer throw-away goods, produce more products of quality and durability and create less waste, promote reuse and recycling, and increase levels of employment. Also, there is need for a broad-based strategy that addresses not only environmental and economic concerns but also social, political, and ethical aspects of sustainable development. Business should have a clear policy in six areas—the six E's—viz., environment, empowerment, economics, ethics, equity, and education (Welford, 1997).

While companies are undergoing transformations, governments, at least in some developing countries, are somewhat lethargic in matching the efforts of the environmentally-proactive companies. Furthermore, the enforcement wing in these countries is often not effective. Policy makers need to develop better understanding of the forces driving corporate environmental responsibility, and to strengthen due implementation and enforcement of environmental laws.

ENABLING TECHNOLOGIES

A careful analysis of some 1500 forecasts of the future of science, technology, and engineering made in Europe, the US, and Japan since 1970 has provided some useful insights into the shape of things that we may come across by the year 2025 (see Coates, 1998). He identified six enabling technologies that are likely to be helpful in shaping the next generation and beyond. These six technologies include information technology, energy, materials, and genetics. The fifth—environmentalism—is strictly not a technology, but it will have such a profound effect on all kinds of technological decision-making that it would have to be put on an equal footing with the other areas. The final area is brain technology for which scientific knowledge (about the brain and mental processes) is now emerging rapidly.

Information Technology

Information technology has already begun to affect everything from our personal lives to global management, and all businesses are now essentially information machines that only incidentally make particular products, largely because it has become possible to couple computers to low-cost telecommunication networks. The continuing increase in computer power will make all information management cheaper, faster, and ever more reliable.

More powerful computers will open up new opportunities in real-time management. The traditional way of dealing with a business problem is extremely slow and involves attempts to analyze the situation, decide what should be done, implement some of the options, and then study their effects. Information technology can drastically change that cycle. For instance, by wiring up enough of the road intersections in our cities to central processors, we can reduce congestion and make traffic travel faster. The same concept could be applied to any other social, political, economic or physical problem.

Genetic Technology

Genetics will revolutionize our lives. The Human Genome Project will enable us to identify the loci of some 4500 diseases and disorders and generate new research to identify the links between our genes and the manifestation of particular conditions. There will be a boom in pharmacological and gene-therapeutic approaches to deal with these conditions.

The new genetic knowledge will be used to enhance human life. Genetic technology will eliminate specific conditions. The new knowledge will influence decisions about marriage, conception, and abortion.

Molecular genetics applied to agriculture will expand our diet and make food more nutritious and tasty. Genetic manipulation will allow enhancement in the quality of the thousands of plants that are currently inedible and bring them into our diet. The ability to combine characteristics of one plant with another will become routine within a decade. Plant genetics will enable us to modify plants to grow in hostile environments.

Microorganisms, which only do what their genes program them to do, may come to operate as miniature 'factories', producing not just exotic materials but even commodity chemicals. As molecular biologists become more skilled at changing genome structures and basic enzymes, we acquire the ability to produce materials that do not exist in nature.

Materials Technology

The materials revolution has been occurring silently. It is now possible to go beyond the intrinsic constraints imposed by the materials at our disposal, for example, in the case of the new metals, alloys, and plastics of today. We should soon be able to create materials with any characteristics we desire. Glasses that conduct electricity or are photosensitive are well within the practical range of development, as is cement that can flex (Coates, 1998).

Composites could replace the heavy steel frame of a vehicle and make cars up to six times more efficient. And by replacing the engine and the drive train with electric motors and a small source of energy from a fuel cell, vehicles could travel for around 100 miles per gallon.

Energy and Environment

Warming from greenhouse gases appears to be real and significant. Our use of energy will be a continuing problem in the first two decades of the twenty-first century. Therefore, there will be a massive drive towards energy conservation, particularly of fossil fuels, that will lead to a boom in new designs of buildings, structures, devices, transportation systems, and industrial processes. In a worst case scenario, we may also require new energy sources.

There are two main choices. First, we can turn to nuclear power, probably following the French model of using simple, uniform platform plants that would provide many economies of scale. The second option is photovoltaics, in which sunlight is converted directly into electricity. A further attractive option may be wind energy. Since global warming is likely to create a more turbulent atmosphere, wind energy may be another good option.

Today, the obstacles to the wider use of nuclear power are political, e.g., how to prevent dangerous materials from leaking or being used in weapons. Photovoltaic energy is too expensive to compete with centrally-generated power but has a market in remote areas and for powerng isolated devices.

Brain Technology

The most interesting of the emerging developments in science and technology may be brain technology. Till recently, our understanding of how the brain works used to rely mainly on case studies of people who had accidents or strokes. Now, new techniques, e.g., magnetic resonance imaging (MRI) and positron emission tomography, allow us to probe and identify the bases of specific mental, physiological, hormonal, cognitive, personality, emotional, and pathological conditions. One major breakthrough is Prozac, a drug that seems for most users to be free of side-effects.

The traditional conceptual barriers between physical and biological sciences are now disappearing. For example, the emerging science of complexity is not limited to physical systems but has important applications in biology. Similarly, the work in fractals and chaos has applications across all of science. With this increased overlap between disciplines, we will enjoy many alternative ways of turning ideas into practical application. What is desirable is to see across this full range of choices (Coates, 1998).

HUMAN RIGHTS

One question that has cropped up in recent years and which mirrors the concerns of a large number of people around the world is: Can the strong polarizing trends of the past few decades be offset by new approaches that reaffirm the basic civil, political, and socio-economic rights of every human being? A new rights-based approach to development issues has gathered momentum as a growing number of people have been affected by economic restructuring or by discrimination of various kinds of demand. The definition and protection of socio-economic rights—besides basic civil and political rights—have become very important.

A rights-based perspective on development can be strengthened in several ways. Firstly, it helps us to analyze the process of rapid social and economic change, now usually subsumed under the general heading of globalization, that forms the backdrop for growing polarization and exclusion. Secondly, going beyond human rights *per se*, it frames the challenge of defining and protecting these rights in terms of the construction and defence of citizenship.

Globalization means different things to different people. To some extent, it has become an ideology, orienting the future actions and expectations of groups within the corporate world. As an ideology of market expansion, it brooks no alternatives: it decrees the victory of global capitalism over national control, and the independence of economics from politics. However, this extreme view is not accepted by many people who feel that globalization is too complex a phenomenon to be defined precisely.

The increasing interconnectedness of all people around the world emanates from concrete developments which reflect the accumulated decisions of concrete groups. Even the revolution in information technology and communications that now shapes construction of a 'global village' has strong social roots. And the process of rapid economic liberalization that reduces the manoeuvrability of national governments, in both economic and social policy fields, has been significantly facilitated through various alliances and agreements that underpin the working of so-called market forces (UNRISD, 1998).

Citizenship has become a metaphor for social protection and for the guaranteeing of basic rights in particularly chaotic times. Traditionally, citizenship has come to be associated with the consolidation of secular nationalism. In Europe, the struggle over citizenship during the seventeenth and eighteenth centuries meant respect for individual civil and political rights and assured formal equality under law, irrespective of wealth, ethnic background or religious affiliation. Subsequently, social, economic, and even cultural entitlements became part of citizens' rights in western Europe and America, and the ideals of citizenship were integrated into nationalist views of progress in many other countries. But in the last two decades of the twentieth century, the struggle to define and defend rights has often crossed the borders of any particular country; and with increasing frequency, the elements of citizenship are being construed not only in national settings, but also in subnational and supranational contexts, ranging from the regional to the global (UNRISD, 1998).

This has happened not only because some nations failed to defend the basic rights of their citizens, but also because—as a corollary of globalization—the boundaries of solidarity among various kinds of people are changing. New identities are being reinforced and new issues (including global environmental protection) have become conspicuous by their presence in the international agenda.

The expansion of transnational identities and markets, as also the effect of migration and multicultural contact, are affecting the parameters of citizenship in the oldest and best-established 'citizen states'. Secondly, the current struggle to create or strengthen democratic institutions in the Third World and the former Soviet bloc is being waged not only under the banner of rights, but also in the name of the citizen (see Davidson and Weekley, 1999). Becoming a citizen, even in the most traditional sense (the guarantee of individual rights within the boundaries of an independent nation), is one of the great mobilizing ideas of the late twentieth century. We need to think carefully about the peculiar challenges associated with building citizen states in the context of economic, social, and cultural globalization (UNRISD, 1997, 1998).

Some potentially promising approaches are now available for such fields as mobilizing resources for social development; learning from successful attempts to provide universal social services; promoting harmony in countries torn by civil war; and developing community-based approaches to urban social problems. Whereas certain initiatives have indeed given positive results at the local or national level, responses at the international level have not been strong enough for these to gain any real momentum globally. Global economic liberalization poses serious challenges to workers engaged in reducing unemployment and poverty, and to promote social solidarity. In the face of an often unfavourable economic environment, NGOs (non-governmental organizations) confront the dilemma of how best to further their own programmes of action. If they enlarge or scale up their efforts, they risk becoming the mirror image of large, bureaucratic institutions, with all the attendant problems of accountability and effectiveness. If they become partners of international financial institutions, they risk co-optation. On the other hand, if they limit themselves only to the local or regional scale, and refuse important outside resources, their efforts usually remain fragmented and insignificant (UNRISD, 1998).

The need of the hour is for organizations working for broad-based social development to improve their capacity to encourage and support economic policies that will reduce social costs.

2

History of Human Ecology

INTRODUCTION

Human attitudes in many parts of the world have ranged, over the past 10,000 years, from a deep respect for land and sea to a belief that exploiting resources to the point of destruction is the inevitable price of progress. A new set of ideas has emerged in the last decade, viz., the concept of sustainability; this concept gives a fresh measure for our utilization of the natural resources to which the future of the world is closely linked.

Human history of the past four centuries suggests that the particular resources that society is trying to sustain shift over time, sometimes dramatically. In the eighteenth century, in several kingdoms, ministers spent much time and money trying to sustain supplies of masts from forests. Today, while large trees are valuable, there is no market for mast pines. As forest conditions and wood supply have changed, so also have demands for them.

There is a tendency to view sustainability as retaining the industry of today, as preserving traditional ways of life. Yet economic history has several instances exemplifying that change has been the way of life in many regions. We no longer build wooden ships or load fuelwood and granite onto schooners, nor pack lobsters in cans. Efforts to freeze the past are doomed to failure; what is important for local communities is the ability to adapt.

The idea of sustainability is a complex one. Its applicability in practice depends on its relation to the economic base of local communities. It is important to understand how our competitiveness relates to other resource-rich areas. Also, we must appreciate the ecosystem functions of our forests and waters.

Sustainability has special meaning for regions that are heavily dependent on fossil fuels, metals, and foodstuffs imported from elsewhere. These supplies cannot be taken for granted—we just cannot simply produce less of whatever seems inconvenient and buy the rest from elsewhere. Any region that takes sustainability seriously must make all efforts to improve its self-sufficiency in many products, at the same time closing materials cycles and reducing its use of energy and materials.

A particular meaning of sustainability attracted limelight recently: managing lands and fisheries to maintain and enhance ecosystem process and functions, instead of simply to maintain annual yields of products. Our present meagre knowledge of ecosystems enables us to see ways of how we might improve things. Yet there is a danger in arguing that pristine, presettlement conditions should be the standard of comparison toward which all resource management should be directed. The past four centuries have seen the introduction of non-native diseases, the extinction of species, and significant changes in ecosystem structures. The climate itself has changed, perhaps in ways more significant than we realize, and the world's population is much larger than it was a few centuries ago.

Today, there is simply no new place on earth to find unexploited forests or fisheries; no open space into which cities and suburbs can continue their historical expansion without affecting some aspect of local biodiversity; no refuge in the ocean where marine life is undisturbed; no stretch of shoreline or beach where human competition for natural resources is not already fierce (Platt *et al.*, 1996).

Whatever we now accept as part of our civilization needs to be judged by new standards: we must make more out of less; we must accept the strongly radical idea that all resources on which we depend are inherently limited; we must learn to think in cycles. We must realize whatever we produce involves costs for the environment.

There are several regions (e.g., the Gulf of Maine) in which clear and deep ecological connections can be seen between forest uses, river quality, and marine life (Platt *et al.*, 1996). The circular gyre of currents in the Gulf of Maine and the geomorphology of a sea within a sea represent fundamental ecological conditions that bring out clearly the concept of the structure of cycling and recycling mechanisms in nature. What goes around comes around; shifting environmental problems from one part of the biosphere to another—from land to water, from fossil fuels to the atmosphere—is not a sustainable practice.

Defining ecosystem health and function in those regions which have heavily used and modified forests and waters is a challenging task (Platt *et al.*, 1996).

Environmentalists have to carry a dual burden: (1) how to convey a sense of joy and wonder in appreciation of the natural world; and (2) how best to inform about impending doom, warning the world about ecological disasters.

This dual burden reminds one of a good analogy of property ownership. The idea of owning a property has contradictions. We are simultaneously liberated and imprisoned by property. It protects us from the tyranny of the state just as it is used as a form of coercion. It is a means of personal wealth just as it involves the prospect of exploitation (see Thomashow, 1995).

ENVIRONMENT AND CULTURE

If we follow Shakespeare's dictum "What is past is prologue", then a clear understanding of not only how the earth works, but how it worked, is essential to frame effective environmental policies for the future—a challenging task requiring meaningful integration of environmental and cultural data at diverse temporal and spatial scales. Historical ecology depends on concepts from both the natural sciences (e.g., biology, geology, climatology) and the humanities and social sciences (history, anthropology, geography, and archaeology). Historical ecology deals with specific times and places which shape human interaction with the environment. These perspectives are acquired by learning and vary widely not only from society to society but also between generations. Study of changing landscapes can point to the role of humans in modifying the global ecosystem. It has now become possible to ask critical questions about how human beings affect and are in turn affected by their environments. In contrast to the early twentieth century theories of human/environment relations, current research does not assume a deterministic role for the environment: we now have several examples of how humans can cause fluctuations in resources or climate and also respond to them (Crumley, 1995).

Some difficulties have slowed down the building of a connecting bridge between science and history. One has been the very different scales at which atmospheric phenomena and human activity are observed. The interconnectivity of the atmosphere, hydrosphere, biosphere, and geosphere in the global system has been well recognized but the cultural and historical differences prevailing in societies make many global-scale generalizations about *Homo sapiens* virtually meaningless. Though settlement and land use patterns or, for example, gaseous emissions, must be investigated at regional and local scales, it is at the global scale that the collective effects of mankind's activities need to be checked (Crumley, 1995).

Changes in the global environment can alter the capacity of the earth to sustain life. These changes will affect everybody on the earth. Indeed, human activities now compete with natural cycles to change earth systems. Past climate changes (e.g., ice ages) have been signalled by a change of 85 ppmv of CO_2 in the atmosphere. Humans have now contributed over 100 ppmv of CO_2 and additional amounts of other greenhouse gases to the atmosphere in the two centuries since the beginning of the industrial revolution. These figures place anthropogenic activity on an equal level with natural processes as regards the potential to effect global climate changes.

The layman usually lacks an understanding of the issues, confusing weather with climate or ozone loss with greenhouse warming. Many people do not understand that CO_2 from fossil fuel emissions is the main culprit in global warming.

Twenty-five centuries ago, Aristotle had opined that what is common to the highest number gets the least care. Humans pay most attention to what is their own and care less for what is common. The same idea was echoed more recently by Garrett Hardin in the context of his tragedy of the commons: in the absence of effective regulation, people pursuing their private interests with common resources inevitably overexploit them. Such tragedies of the commons are routine wherever regulation of common resources, e.g., fisheries, pastures, and water, is weak. A popular remedy today for the situation is privatization. This was the wisdom of

Aristotle, and it is also the preference of most economists and politicians. But it need not always necessarily be appropriate wisdom. Twenty-five decades ago, the French philosopher Montesquieu stated that different lands require different laws, including, for instance, property laws. The history of land privatization in some countries, e.g., Spain, attests to the veracity of his statement. Unregulated privatization of common or public resources, howsoever consistent with current advanced thinking, can lead to ecological costs that eventually eclipse any economic benefits.

No unified theory of how humans interact with their environment is available. Common theoretical ground between science and the humanities needs to be found. Established natural scientific approaches reveal environmental change, while an emerging integrated social science approach brings out the extent of changes in human activity in the course of time.

The impacts of environmental hazards represent the product of the interaction between events in the physical environment and characteristics of society. This is seen from the fact that whereas a flood, storm or earthquake usually takes a much heavier toll of victims in any developing country than in a developed one, property losses tend to be much higher in developed countries. While physical scientists study the biophysical changes now occurring in the global environment, ongoing macro-social changes interact with physical changes to effect the distribution of the consequences and causes of environmental changes. It seems certain that urbanization, population growth, increasing poverty, global economic changes, commodification of agricultural production in developing countries, and international migrations all will contribute to reshape the dynamics of interactions between nature and society.

SCIENCE AND TECHNOLOGY

If the world's people think of the legacy they will be leaving to their progeny, vigorous efforts surely will be forthcoming to ensure, while there is still time, that the shameful trends seen in the twentieth century are soon reversed. There is much to do. The indifference that now greets barbaric military practices, the acceptance of vast disparities in wealth, the willingness to desecrate the planet's environmental future in return for immediate gain, the apparent abandonment of commitments to justice and decency and equity—these attributes of the late twentieth century are surely not the kind that statesmen anywhere will wish to have engraved on their tombstones. It is ironical that the human species now has all the knowledge and all the resources necessary to mount a magnificent tribute to humanitarianism: knowledge that empowers us to undertake steps required to implement new policies; resources that are now wasted in nonproductive, often military-related ways. One of the available instruments takes the form of technology.

In all history, technology has been the most powerful of change agents.

But to be beneficial, science and technology have to be shaped and directed by wise policies. Science and technology hold out much promise to the developing countries; promise to grow nutritious food, to protect health, to provide shelter and education, to husband the environment. But without wise policies in all countries, that promise melts away in the face of greed and privilege. In human terms, it means that the grip of absolute poverty will not be eased and that the scourges of malnutrition and ill health will persist. What is needed is to foster the advent of a world where science and technology will be used everywhere to solve global problems (IDRC, 1991).

BEHAVIOURAL ECOLOGY OF MODERN HUNTER-GATHERERS

Agriculture is in many cases less than 10,000 years old in human experience. There are some tribes whose members still live by hunting and gathering and they can give us informative windows on our evolutionary past. Every continent has seen great changes in the distribution of human populations following the establishment of modern climatic conditions some 8000–10,000 years ago. Migration, war, trade, and conquest have occurred repeatedly. Many contemporary hunters have recent farming or herding ancestors. Modern foragers may be seen not as a key source of information about human evolution, but as members of a worldwide, dispossessed rural proletariat, which is of no special interest to those studying the distant past (Hawkes *et al.*, 1997). But if relationships between constraints, trade-offs, and variability in behaviour can be understood in general terms, then such an understanding can generate hypotheses about human behaviour in the past which we cannot observe directly.

Humans always forage selectively, using only a few of the plants and animals found in any locality. Their choices vary through time and space. In general, human foragers select those food resources which maximize mean rates of nutrient intake. They routinely bypass resources yielding relatively low post-encounter rates when more profitable items are common, but exploit a wider choice of prey when those items are rare. About 20,000 years ago, human populations started exploiting locally-abundant, nutrient-rich, but till then unused, resources such as seeds and other plant foods that need much processing to improve digestibility or to remove toxic matter. This broad spectrum revolution appears to have marked a decline in encounter rates for higher ranked prey (Hawkes *et al.*, 1997). Broad spectrum foragers spend more time in processing than searching, and so have more to gain from improvements in processing efficiency, including those gained from actively manipulating resource characteristics. It is this which makes broad spectrum diets a common, essential precursor to agriculture. Not all broad spectrum plants got domesticated, and not all broad spectrum foragers moved on to farming, because only a few species of plants and animals have the reproductive habits and genetic make-up that allow relatively rapid improvements in handling efficiency

(Hawkes *et al.*, 1997).

Processing practices also greatly affect nature and distribution of the refuse they produce. It is important to understand these effects so as to know about past foraging patterns. When foragers transport food to eat at a central place, bulky, heavy, more durable, and persistent components, such as animal bones, mollusc shells, and the hard, inedible parts of certain plants, tend to be discarded at or near the place of acquisition. Relationships between actual diet and food waste left at the place of consumption (usually a residential base) are skewed accordingly. There are indications that differential transport and discard are highly systematic processes, quite consistent with the goal of maximizing the nutrient value of loads transported, given the constraints of time and transport capacity.

Despite the general pattern of maximizing nutrient acquisition rates, hunting and gathering are not always consistent with this goal. By and large, men prefer large animal prey and ignore plant foods profitable enough to increase their mean acquisition rates. Women frequently do just the opposite, taking plants and other small, more predictable resources, but not large animals (Cronk, 1991; Kelly, 1995). There are two hypotheses to account for this pattern. One attributes the pattern to the joint effect of (1) macronutrient composition of resources, and (2) incompatibility of hunting and child care. Men may be maximizing their mean rate of nutrient gain in a form that gives higher weight to fat and protein than to carbohydrates; women may avoid hunting because of the associated costs in child welfare (Hawkes *et al.*, 1997).

The second view emphasizes resource predictability and dependability and their effects on patterns in foraging returns. Men favour prey that are irregularly acquired and widely shared whereas women go for foods that give a predictable daily nutrient supply.

Food-sharing is much more common among humans than among other primates. Among modern hunters, sharing varies with resource characteristics: large, unpredictably acquired food sources are shared more widely than smaller items taken more regularly. This may involve reduction: successful hunters give some of their catch to the unsuccessful in anticipation of a time when their respective fortunes might become reversed.

Children can be quite adept at foraging. It is not true to say that they are less productive among hunter-gatherers than among farmers. Mothers routinely adjust their own foraging tactics to take advantage of their children's capabilities, choosing resources that give them lower personal return rates but maximize the returns they and their children earn collectively.

The more dependent children are on food supplied by their mother, the larger the impact a helper could have on mother's fertility. If someone else provides nutrients to the child she is about to wean, the mother can divert her effort to the next baby sooner. Logically, this role falls on her husband, the children's father, thereby establishing the nuclear family as a unit of common economic and reproductive interest.

Recent studies suggest that individuals adjust their foraging behaviour according to age, sex, and reproductive status, relative to features of local ecology, including the age, sex, and reproductive status of other members of their local group. Men often pursue resources that, once taken, attract many claimants. Women take foods they can subsequently control, their specific choices often depending on a trade off between their own acquisition rates and those of their children (Hawkes *et al.*, 1997).

Foraging patterns form part of reproductive strategies and interact with the timing and rate of life course events.

HUMAN ECOLOGY IN INDIA

The diversity of ecological niches that India's huge population of about one billion collectively occupies is as enormous as that of the belief systems, practices, and regulations that govern the utilization of its natural resource base. Many Indian towns still have wild populations of monkeys, thanks to the religious protection they enjoy, but the vast populations of many other species of wildlife that once roamed its countryside are all but gone. While farmers fight bitterly over boundaries of fields in the irrigated tracts of Rajasthan, tribal peoples of the North-East practise shifting cultivation on communally-owned land. While village grazing lands are encroached upon for cultivation, state forests are often used for the production of eucalyptus for industry (Gadgil and Thapar, 1990).

The Indian subcontinent has had a long geological history. It has the Himalaya, the tallest mountains in the world. This mountainous barrier has been continually rising over the last 50 million years, and most mammals have come to India through passes to the west or the east of the Himalaya. Hominid fossils first appeared in the Himalayan foothills 13 million years ago, continuing till 7 million years before present as a part of mammalian communities of wooded habitats. They then disappeared, presumably victims of habitat changes brought about by the continuing uplift of the Himalaya. Much later, members of the genus *Homo* arrived in the subcontinent, probably from their place of origin on the savannahs of East and South Africa. Tool-using hominids arose in Africa some two million years ago; by one million years they had reached Java. Firm evidence of human occupation of India appears between 700,000 years and 400,000 years ago by which time the uplift of the Himalaya was completed and a seasonal monsoonal climate had become established.

The hunter-gatherer populations of the species *Homo sapiens* covered much of the country thinly during the remaining part of the Late Pleistocene, when the climate fluctuated between periods of weak, moderate, and strong monsoon. The wet hilly tracts of the Western Ghats, the West Coast and the north-eastern hill regions as well as the Gangetic plains, however, remained unoccupied until the Terminal Pleistocene, 20,000 B.P., when the monsoons became distinctly weak at the height of glaciation in the northern latitudes (see Table 2.1).

In productive, stable environments, hunter-gatherers and shifting cultivators maintained well-defined territories. Cycles of materials in such environments were largely closed within the spatial scales of territories, with flows of materials across territorial boundaries being much less significant (Gadgil and Thapar, 1990).

The social relationships amongst members of the early tribes were governed by kinship and mutual help. Their belief systems extended these relationships from the social to the natural environment. Many elements of natural environment were protected. The resultant protection of elements of environment, be they ponds or groves or all members of a species such as the pipal tree (*Ficus religiosa*), served to promote long-term persistence of biological resources. Many such practices have continued to the present day and have helped protect a wide diversity of biological resources (Martin, 1978; Gadgil, 1985).

The receding of the forest cover associated with climatic changes probably created a food crisis prompting hunter-gatherer societies to domesticate animals and cultivate plants. The crisis was perhaps most serious in the Middle East, where domestication of animals, and cultivation of plants began to gather momentum some 10,000 years ago. Wheat, barley, lentils, and cattle, sheep, goats were first domesticated there, and this change undoubtedly also provided the stimulus for the beginning of agriculture and animal husbandry on the subcontinent. Some pulses, e.g., horse gram, green gram, and black gram, were indigenously brought under cultivation in India around 4000 years ago. The humped cattle, the zebu, is also likely to have been independently domesticated on the Indian subcontinent. It is these cattle and pulses that give Indian agriculture and animal husbandry its special character (Kajale, 1988; Gadgil and Thapar, 1990).

Husbanding of plants and animals radically transforms the ecological niche of human societies. Hunter-gatherers depend on a tremendous variety of plant and animal foods, ranging from insects and fish to mammals as large as elephants, and from tubers and grass seeds to the pith of palm trees and fleshy fruits. Agricultural-pastoral people tend a smaller number of plant and animal species but the level of production per unit area from these species is much greater. Hunting-gathering does not generate easily stored surplus harvests but husbanding does so. Cereal grain or meat on the hoof produced in the region can then be moved to distant localities. This encourages material flows over spatially much larger scales (Fig. 2.1), disrupting the smaller closed cycles of erstwhile tribal territories. This transformation of the material flows in turn affects social organization. An intensively-cultivated plot of land or an intensively-tended herd of animals is more effectively looked after by a small group of people, the family unit. The generation of surplus by agriculture and animal husbandry opens up new dimensions of the human niche, and some individuals can subsist entirely by usurping the surplus of others.

Agricultural-pastoral people had an edge over hunter-gatherers when-

Table 2.1 Climatic history of Indian subcontinent (after Gadgil and Thapar, 1990)

Geological period	Years ago	Climate	Geomorphic data	Human population
Late Holocene	<4000	Moderate monsoons	Saline lakes in western India	Agricultural settlements cover the subcontinent
Early Holocene	10,000–4000	Strong monsoons	Freshwater lakes, entrenched streams, stable dunes	Beginning of agriculture, denser populations
Terminal Pleistocene	20,000–10,000	Distinctly weak monsoons	Hypersaline lakes, choked rivers, active dunes	Human population spread throughout the subcontinent at low densities
Late Pleistocene	70,000–20,000	Weak to moderate monsoons	Entrenched streams, stable dunes	Hunter-gatherers in small groups, wetter tracts not colonized
Early Late Pleistocene	125,000–70,000	Strong monsoons	Reddish soils (dating doubtful)	Hunter-gatherers in small groups, nomadic
Middle Pleistocene	700,000–125,000	Monsoonal seasonal climate		First evidence of human occupation
Lower Pleistocene	2.0–0.7 million	Relatively dry seasonal climate	Volcanic ashes, streams	Hominids found in both Africa and Java, but no definite evidence of human occupation in India
Pliocene	8–2 million	Tropical equatorial to strongly monsoonal (?)	Volcanic ashes	
Miocene	25 million	Tropical equatorial (?)		

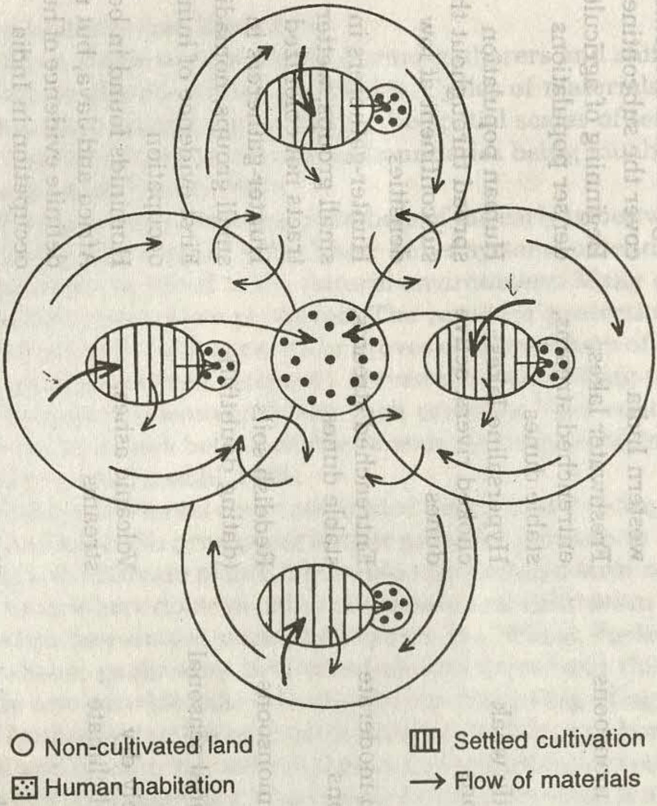


Fig. 2.1 Material flows in an agrarian society (after Gadgil and Thapar, 1990).

ever there was some dispute over land. The population densities of the former would be greater, and their surpluses would enable them to keep fighting for a longer period. The technology of agriculture and pastoralism would then tend to spread into regions suitable for this mode of resource use. Hunter-gatherers were gradually outcompeted from ecological niches suitable to agricultural-pastoral people.

Agricultural-pastoral people who lacked metal tools could not penetrate the moister forests of the Gangetic plains or the West Coast. The habitat most favourable to them for cultivation was along the smaller watercourses in the drier tracts of north-western India, the Indus plains and the Deccan peninsula. This is where agricultural settlements developed over the period 6000–1000 B.C. There was also animal husbandry, including nomadic cattle herding, and this has left traces such as the ash mounds of the Deccan Plateau.

RIVER VALLEY CIVILIZATIONS

The first urban civilization of the Indian subcontinent covered a wide region of the North-West and knew how to use the plough. They also began to add indigenous rainy-season crops such as rice and pulses to the winter crops of wheat, barley, and lentils of West Asian origin. The agricultural surpluses thus produced permitted the establishment of many towns, where the surplus served to promote further processing and exchange of materials, as well as artisanal and trade activities (Gadgil and Thapar, 1990). Exchange over distances generated the need for maintenance of records, and the Indus Valley Civilization was probably the first to evolve literacy in Indian history (Possehl, 1982). Gradually, there was weakening and disappearance of the urban centres of this civilization probably because of shifting of the river courses due to geological changes associated with the continuing uplift of the Himalaya. It appears that the river Saraswati dried up when the Sutlej shifted its course westward to join the Indus and the Yamuna shifted eastward to join the Ganga.

Iron was introduced to India before about 1000 B.C., and was associated with the Painted Grey Ware pottery culture of the North-West, the Black and Red Ware pottery culture of Central India, and the megalithic cultures covering much of the peninsula. Use of iron and fire helped bring the middle Gangetic plains under intensive agricultural-pastoral colonization, with wet-paddy cultivation as a key element. *Yajnas*, the large-scale sacrificial rituals involving the burning of vast quantities of wood and animal fat, catalyzed this process: Brahman priests moved into forests to establish outposts and clear forests. The native inhabitants opposed to *yajnas* were regarded as demons, from whom the Kshatriyas, the warrior caste, protected the Brahmans. The caste system arose. The colonization of the fertile plains of the Ganga occurred in the first millennium B.C.

A density of 0.75 people per km^2 for Kanpur District in the Ganga-Yamuna divide for the Black and Red Ware period around 1350 B.C. has been suggested (Gadgil and Thapar, 1990). The resource base was used exhaustively with the *yajna* as its main element. If, as seems likely, the human population quadrupled over the next eight centuries of agricultural growth, then much of the most fertile land would have come under the plough, and the livestock-to-man ratios and the amount of forest land available for further colonization fell. The society then needed a new belief system, stressing more careful, more sustainable resource use. This new belief system appealed to the agricultural-pastoral population, while Brahmans, beneficiaries of the *yajna* system, opposed it. Buddhism and Jainism may have emerged as responses to this need, with their protests against the hegemony of Brahmans and the wasteful burning of endless quantities of clarified butter and of wood and the slaughter of animals at the sacrificial rituals (Thapar, 1984).

During the Maurya empire which flourished from the fourth century B.C. to the second century B.C., there were large surplus tracts of fertile lands in the Indo-Gangetic plains. There was occasional resort to an irrigation system, and prisoners of war were employed as agricultural labour. The state endeavoured to enhance its revenue by clearing forest to extend agriculture. However, this was controlled and the cutting of forests without permission from the state was prohibited. Forests, rivers, and hills as natural topographical features formed boundaries between the kingdoms. Forests as frontier zones were deliberately maintained in order to provide the required flexibility of boundaries between the states (Gadgil and Thapar, 1990). These forests also supplied elephants for the armies and any person found to have killed an elephant was sentenced to death. Nevertheless, the next two millennia witnessed the elimination of elephant populations from one region after another over the Indian subcontinent, the imposition of taboos on hunting of elephants notwithstanding.

The trade at that period greatly increased the demand for many other resources and commodities, e.g., animal furs and musk, sandalwood, and timber for shipbuilding. Some of these were overused and exhausted. Ashoka's edicts in the third century B.C. and the Jain tradition preached the shunning of violence. A need for a belief system oriented towards a more and more sustainable resource use gradually developed. The Indo-Gangetic plains after the fifth century of the Christian Era saw resource shortages. Indian society responded to this crisis through an elaboration of the caste system. The caste system divided the society into innumerable endogamous groups within which most marriages and much social intercourse became restricted. The endogamous groups of caste society traditionally resembled tribal groups, from which they might in large part have originated. Each endogamous group followed the customary pursuits of the group. In tribal societies, the different endogamous groups usually have non-overlapping distributions, whereas in a caste society several endogamous groups tend to live together (Dumont, 1980).

The sedentary fraction of the human community was complemented by a nomadic fraction. These nomads served as well-diggers or fortune-tellers. They also traded in salt, and consumer goods. The nomads tapped the forest, grazing land, and wild animal resources of tracts away from settled villages. Their modes of subsistence were diversified and often monopolized over certain resources of certain regions, and had developed traditions of their sustainable use. In Maharashtra, for example, hunting of blackbuck was the exclusive privilege of some special tribes who used to release any fawn or pregnant doe caught in their snares.

DISEQUILIBRIUM AND NEW TECHNOLOGY

It is plausible that this organization conferred on the caste society a greater potential for sustainable resource use and perhaps led to an equilibrium in some habitats and with respect to some specific resources. However, population pressure probably continued to mount throughout this period, even if the population growth rate was rather low. The Persian wheel, probably introduced in the seventh century of the Christian Era, improved well irrigation in many parts of northern India, catalyzed agricultural production, and allowed certain castes with access to such technology to exert control over those who lacked it. In the Kaveri valley in Tamil Nadu, the locally-controlled tank irrigation was superseded by canals and systems of water control on the rivers built by the Chola rulers in the late first and early second millennium of the Christian Era. The introduction of such new means of irrigation points to some disequilibrium in the control of resources. Indigenous medicine men dealt with naturally-occurring herbs but did not have access to formalized medical knowledge contained in the Sanskrit texts of ayurveda, while the Brahmans who studied such texts were not in touch with natural plant life. This anomaly led to the failure of the scientific method to develop in India as it did in Europe.

During the Mughal period from the sixteenth century onwards, there was no great difference in the manner in which Indian society functioned, but their mastery over horses and gunpower enabled them to mop up surpluses over larger spatial scales and thereby build up an empire. It was by then a society which emphasized closed cycles of materials from the non-cultivated lands of the village. These were flows of materials out of the cultivated lands, in the form of surplus grain collected as tax by the state, but the state taxed animal holdings very lightly, and forests and fisheries not at all. In fact, Shahjahan even removed a governor of Kashmir when the latter attempted to tax sheep flocks and fishing. Likewise, a ruler of Jodhpur had to abandon an attempt to harvest *Prosopis cinerarea* trees from the village of Khejadli when the local Bishnoi villagers chose to die rather than permit the cutting of trees sacred to them. Apart from claiming exclusive rights over hunting game, the state interfered little in the gathering of other forest produce from these lands by villagers.

HISTORY OF POPULATION GROWTH

Population estimates for the subcontinent at the beginning of the seventeenth century vary between 110 million and 145 million. There were pockets of overutilization of resources as well as areas of underutilization. In the eighteenth century, the Indian people and ecology were profoundly affected by European colonialism. The Indian society had remained largely in equilibrium with its resource base over much of the Christian Era. In contrast, the European society had evolved along very different lines. The European societies discovered the scientific method basic to the growth of knowledge and Christianity stressed intensification rather than conservative use of the resource base. The European society evolved major innovations in processing of resources and greatly increasing access to energy trapped in fossil fuels. The result was tremendously-enhanced abilities to process, transport, and usurp resources, opening up entirely new dimensions for the human ecological niche, just as food production had done at the end of Pleistocene glaciation. The Europeans usurped the niches of the hunter-gatherers and primitive farmers in all areas of moderate rainfall and moderate temperature. The European societies regarded other societies as uncivilized and primitive, just as agricultural-pastoral people colonizing the Gangetic plains had viewed the indigenous peoples as demons. Further, the expanding society venerated the market-place and developed a culture of unlimited consumption of all sorts of materials that by then had become commodities.

The British had strong coercive powers and more efficient methods of transport and communication and could bring the whole country under a single rule. Estimates of population size in the early nineteenth century range from 125 million to 210 million; the census of 1872 gives a more definite figure of 255 million. This indicates a favourable effect of the British colonialism on the growth of the Indian population (Gadgil and Thapar, 1990).

The population growth, however, suffered a setback in the late nineteenth century. Whereas the resource usurpers of pre-British India confined themselves to tapping the surplus of grain production from cultivated land, the British, on the other hand, greatly enhanced the material flows out of rural hinterlands through a number of devices. They increased taxation on agricultural production and cash crops such as cotton and jute. They assumed control of vast tracts of non-cultivated lands and dedicated them to the export of teak, deodar, and other timber or of tea and coffee. Thus, lands that were producing a great diversity of plant produce for local consumption, came to produce just a few products: cotton, jute, indigo, teak, deodar, tea, coffee, all for export out of the locality and often out of the country as well (see Gadgil and Guha, 1992). The British usurped the ecological niches of the tribals by displacing them in order to set up tea and coffee estates in some states by banning their shifting cultivation and by destroying their prey through overhunting.

RESOURCE USE

The British rule tended to discourage Indians from moving into niches of resource processing and transport using modern technology. But they had soon to modify this policy in the face of the two world wars: these wars included a struggle for control over resources of the Third World. The Indians then began to industrialize at first haltingly, but with time fairly rapidly. The trades and manufacturing concerns gained much influence because of access to additional sources of energy and materials. After Independence, Indians naturally steered the course of development onto a path beneficial to them, namely, an all-out state-subsidized effort to intensify the use of resources, of land, water, vegetation, minerals, and energy sources (Gadgil and Thapar, 1990).

Resource use intensification has since stepped up the outflow of resources from cultivated as well as the non-cultivated land to resource processors—industry and the urban sector. This level of disruption of material cycles, which ultimately must be balanced, cannot be sustained in the long run and is depressing the productive potential of the cultivated and non-cultivated lands. Levels of groundwater tapped for irrigation are falling because withdrawal substantially exceeds recharge. Large tracts of irrigated lands are becoming saline because of poor drainage. The nutrient capital of agricultural soils in tracts of intensive agriculture is depleting and deficiencies of micronutrients are becoming more and more acute. Excessive levels of fishing by mechanized craft have exhausted stocks of coastal fish and prawn, while the offshore stocks remain underutilized. Forest resources are being overexploited. Industries as well as villagers are moving to places that are farther and farther away and less and less accessible to them. Village grazing lands have shrunken while the livestock grazing on them has increased. The situation has been saved from total disaster by an inflow of irrigation water, agrochemicals, and high-yielding varieties to the agricultural sector. This inflow is restricted to only 20% of the land under cultivation but has enhanced food production to a level adequate to ensure subsistence for the entire population.

TRIBAL COMMUNITIES

The Indian subcontinent has some 55 million tribal people belonging to over 550 tribal communities of 220 ethnic groups, spread over varied geographic and climatic zones. Their vocations range from hunting-gathering and nomadism to agricultural settlements.

With a view to recording the fast-disappearing knowledge system and wisdom, the All India Coordinated Research Project on Ethnobiology was launched in 1982 by the Ministry of Environment, Government of India. The objective was to document various factors of tribal life, culture, and tradition and their impact on the environment. It was also attempted to find ways to preserve biodiversity and to preserve/conserve all traditional belief and knowledge systems that promote conservation-oriented practices and sustainable utilization of local resources by the tribal people.

The project was initiated in the light of the fact that biological resources in the tribal and other backward areas are becoming scarce as a result of their indiscriminate and unplanned management. Till recently, the emphasis has been on the collection and conservation of botanical wealth. Since we are also richly endowed with natural zoological wealth and the tribals find diverse use of these animals for meeting their various requirements, it was felt that the tribal knowledge system on utilization of wild animals should also be investigated. Tribals utilize many species of forest flora and fauna and, if given proper incentives, they can develop small cottage industries and processing units for minor forest products, herbal drugs, and skill for systematic collection of uncultivated materials such as gums, resins, lac, bark, medicinal herbs, wild fruits, and leaves, thus generating employment opportunities for many people under the Integrated Rural Development Programme (IRDP) (Pushpangadan, 1995).

The tribal people of India generally show the characteristic traits of three great races of mankind, viz., Negroid, Europeoid, and Mongoloid.

The earliest existing anthropological type is Negritos coming under the race Australoid of the great race Negroid. This type is represented by natives of the Andaman Islands. The Munda, Santhal, and others of South and Central India represent the Europeoid stock with their predominance in the Narmada-Chhota Nagpur belt. Mongoloid race is mostly found among the tribals of the Himalayan belt and Nicobar Islands. The Government of India has specified 427 different ethnic communities on the basis of their relative antiquity, spatial isolation, history, techno-economic capability, and socio-cultural status.

Each tribal community belongs to a distinct ethnic group and differs in socio-cultural, demographic, ecological, and economical status from other tribes. They have only oral traditions and their languages have no script. Tribals in India occupy about 18% of the total area of the country spread mainly over 21 states and union territories (Table 2.2). About two-thirds of the total tribal population is concentrated in Madhya Pradesh (12 million), Orissa (5.9 million), Bihar (5.8 million), Gujarat (4.85 million), and Rajasthan (4.2 million). In Meghalaya, Nagaland, Mizoram, Arunachal Pradesh, Deodara and Nagar Haveli, and Lakshadweep, the tribal population exceeds 75% (Table 2.2).

Most tribal people live in forests, from which they largely draw their sustenance. Forests provide them food, medicine, and other material requirements. Living in the forests, the tribals have served as the chief labour force in the exploitation of forest resources. Majority of the tribals are engaged in either part-time settled agriculture or shifting cultivation. They, in general, are traditional collectors of minor forest product (MFP) that provides a substantial part of subsistent economy to them. The tribals do not commonly commercialize the forest products; rather they make use of MFP for their domestic consumption and sell part of it to outsiders to meet their small necessities of life. The tribals have also supplied raw materials from forests to nearby villages and towns for several cóttage and rural industries.

FORESTRY

The status of forests has deteriorated during the past few decades from increasing industrialization, building of big dams, power stations, mining operations, urbanization, and development/expansion of railways and telecommunications. These activities hastened forest degradation that further undermined the economic base of the tribals. This forced many tribals to discard their traditional way of living and to drift into the fringes of industrial working sites of nearby cities/towns to become casual or bonded labourers. Some tribals, for their own survival, started cutting down trees and selling them as fuelwood to the general public (Pushpangadan, 1995).

Primitive hunter-gatherer tribes constitute hardly 2–3% of the tribal population and live in isolation mostly in inaccessible mountainous forests

Table 2.2 Some primitive Indian tribes and their vocational habits (after Pushpangadan, 1995)

Tribes	Distribution	General occupation
Andaman and Nicobar Islands		
Great Andamanese, Jarawa	South and Middle Andaman	Hunters, food gatherers
Onge	Little Andaman	
Sentinelese, Shompens	North Sentinel Island, Great Nicobar Island	Hunters, food gatherers, collectors of MFPs*
Andhra Pradesh		
Chenchu, Konda Reddi	Nallamalai Forest (Mehboobnagar District), East and West Godavari and Khammam Districts	Food gatherers, hunters, collectors of MFPs*, labourers
Kolam	Near mountains and foothills	Depend on forest produce
Bihar		
Asur, Birjia	Ranchi and Palamau Districts	Iron smelting, primitive agriculture, slash-and-burn agriculture
Birhor, Korwa	Hazaribagh, Ranchi, Singbhum, Dhanbad, and Palamau	Food gatherers, hunters, bird catchers
Mal Pahariya	Hilltops, hill slopes of Santhal Parganas, Bhagalpur, and Saharsa	Cultivators, hunters, food gatherers, manual workers
Sauria Pahariya	Raj Mahal Hills	Shifting cultivators, hunters, food gatherers, collectors of MFPs*
Gujarat		
Kotwalia, Kathodi	Scattered	Basket makers, fishers, cattle grazers
Karnataka		
Jenu Kuruba	Kodgau	Honey collectors, woodcutters, black magic (prepare snuff from the hood of cobra)

Table 2.2 Some primitive Indian tribes and their vocational habits (after Pushpangadan, 1995) (cont.)

Tribes	Distribution	General occupation
Kerala		
Kurumbas, Cholanaickan	Reserve and vested forests in Palghat, Emad Taluk of Malappuram District	Shifting cultivators, food gatherers, basket makers
Madhya Pradesh		
Abujhmaria	Abujhmarh Hills	Shifting cultivators
Baiga	Mandla, Bilaspur, Shahdol, and Rajnandgaon Districts	Medicine men, laborious axe men, arrow hunters, dependant on forests
Hill or Pahari Korwa	Raigarh, Bilaspur, and Sarguja	Cultivators, collectors of MFPs*, fisheries
Maharashtra		
Katkari	Kolaba and Thane Districts	Agriculturists, forest labourers, fisheries, cattle grazers, collectors of MFPs*
Madia Gond	Bastar and Chandrapur	Shifting cultivators, food gatherers, fishers, hunters, trappers
Kandha	Central and Rayagada Section of Eastern Ghats	Shifting cultivators, horticulture
Tamil Nadu		
Irula, Kota	Nilgiri Hills	Hunters, food gatherers, collectors of MFPs*, cultivators
Kattunayakan, Kurumbars, Toda	Western Ghats, Nilgiri District, Gudalur Taluk	Elephant mahouts, watchmen or workers in forest plantations, labourers
West Bengal		
Toto	NW Jalpaiguri, bordering Bhutan	Porters carrying oranges, shifting cultivators

*MFP, minor forest product.

or islands. They are the most primitive forest-dwelling hunter-gatherers of non-monetized group with stone age type of civilization. They live in isolation in caves or simple makeshift huts and shun outsiders, being very shy and timid. Occasionally they abandon the settlement and migrate to denser forest areas in search of food and to avoid contacts with the outsiders. They depend fully and harmoniously on forests for their life's needs.

Primitive agriculturists include about 5–7% of the tribal population. They are socially better organized than the hunter-gatherers, and maintain some interaction with outsiders. They practise a primitive type of shifting cultivation. Some very primitive cultivars of rice, wheat, sorghum, millets, lentils, pulses, and beans and wild relatives of certain crop plants are cultivated by these tribes.

Simple artisans are mostly nomadic tribes practising elementary iron smelting, tool-making, and metal works or engaged in basket-making and bamboo or cane works. They constitute about 5–7% of the tribal population, and are not well organized.

Pastoral and cattle breeders contribute about 3% of the tribals.

Industrial-urban people are the uprooted tribes that migrated to cities in search of jobs on account of loss of their traditional occupation. Many work as bonded labourers with contractors in construction sites.

ETHNOBIOLOGY

Ethnobiology is the study of association, interaction, and interrelationship of human societies (especially primitive human societies such as tribal and aboriginal communities) with the natural flora and fauna. Primitive and aboriginal communities include the indigenous people of a particular region with little technological development and no written language, thus preserving traditions by oral means and living as a small, economically-independent group.

Ethnobiology embraces such different disciplines as botany, zoology, anthropology, linguistics, sociology, agriculture, archaeology, and even geography for a proper understanding of cultural and biological factors involved in the interrelations of tribal, aboriginal or hill communities with plants and animals.

Ethnobiology includes the following aspects:

(1) Man-plant or -animal interaction in primitive cultures.

(2) Historical understanding based on existing primitive cultures.

(3) Genetic pool of resistant and hardy plant/animal species.

(4) Tribal practices (e.g., herbal medicine) to open new areas of knowledge/treatment/development of drugs.

(5) Development of technology to benefit tribal/hill communities (Pushpangadan, 1995).

Modern researches have attested to the efficacy of many of the crude plant drugs used by aborigines. Several plant-derived 'wonder drugs' with rich ethnopharmaceutical attributes have become known from the tribal and aboriginal societies. The herbal revolution has uncovered the unbelievable muscle relaxants from South American arrow poison, cortisone and contraceptives from sapogenin plants employed by tribals of Central America, India, and Africa, and hypertensive and psychoactive agents from plants used in traditional medicine in India and South America. The development of folk medicine into a drug of therapeutic importance is exemplified by *Rauvolfia serpentina* whose roots are used in Indian medicine as a cure for insanity, epilepsy, and high blood pressure.

Over 9500 wild plant species used by tribals for meeting their varied requirements were recorded. Out of 7500 wild plant species used by tribals for medicinal purposes, several may be new to science. Out of 3900 or more wild plant species used as edibles (as subsidiary foods/vegetables) by tribals, about 800 were not known as such and at least 250 of them may have good potential as alternative sources of food. Similarly, out of over 525 wild plant species used by tribals for fibre and cordage, 50 are promising for commercial exploitation. Out of 400 plant species used as fodder, 100 can be recommended for wider use and out of the 300 wild plant species used as piscicides and pesticides, at least 175 appear promising as safe biopesticides. Almost all the plants used as sources of gum, resin, dye, incense, and perfumes should be investigated critically to determine their commercial suitability as natural sources of these products.

ENDANGERED PLANT SPECIES

Some of the economically-important species are endangered. Some important western Himalayan wild medicinal plants that have now become endangered due to overexploitation are *Aconitum ferox, A. heterophyllum, Angelica glauca, Atropa acuminata, Colchicum luteum, Dioscorea deltoidea, Ephedra gerardiana, Heracleum canescens, Inula recemosa, Orchis latifolia, Juniperus communis, Paeonia emodi, Picrorhiza kurroa, Podophyllum hexandrum, Polygonum alpinum, Nardostachys grandiflora, Rhododendron hypenanthum, Skimmia laureola, Sorbus cuspidata, Swertia chirayita, Tanacetum longifolium, Typhonium diversifolium, Abies webbiana*, and *Abies pindrow.*

Shifting cultivation practised by the tribes of eastern Himalaya has damaged the forest habitat and the sites have become unsuitable for the growth of several rare and endangered species. These include wild relatives of fruit and vegetable species such as *Citrus* spp., *Musa* spp., *Trichosanthes* spp., and medicinal plants, for instance, *Cinnamomum cedicodaphne, Elaeocarpus sphaericus, Alpinia galanga, Chlorophytum arundinaceum, Rauvolfia serpentina, Hedychium* spp., *Piper cubeba, Aristolochia bracteata, Dioscorea prazeri, Aconitum falconeri, Meconopsis betonicifolia, Microstylus wallichii, Nepeta khasiana, Gaultheria seshagiriana, Rheum emodi, Rhus hookeri, Valeriana wallichii, Viola falconeri, Vanilla pilifera, Dalbergia clarkei,* several *Rhododendron* species, and the conifers *Abies delavayi* and *Pinus bhutanica* (Pushpangadan, 1995).

Some threatened plants in the Western Ghats and peninsular India include *Canavalia stocksii, Dolichos bracteatus, Vigna radiata* var. *setulosa, Sesamum laciniatum, S. prostratum, Vigna mungo* var. *sylvestris, Atylosia* spp., *Dioscorea wightii, Rauvolfia serpentina, R. barberi, Hemidesmus indicus, Tinospora malabarica, Capparis moonii, Lobelia inflata, Urginea indica, Amorphophallus commutatus, Curcuma inodora, C. amarissima, Gloriosa superba, Oryza jeyporensis, O. malampuzhaensis, O. nivara, Curculigo orchioides, Abelmoschus tuberculatus, Psoralea* spp., *Withania coagulans, Chlorophytum borivilianum, Crinum brachynema, Tephrosia collina, Lobelia nicotianaefolia, Terminalia pallida,* and *Drosera peltata* (Pushpangadan, 1995).

Ailanthus kurzii, Canarium manii, Amomum fenzlii, Dipterocarpus kerii, Garcinia cadelliana, G. calycina, G. klainii, Mesua manii, Aglaia fusca, Calamus nicobaricus, Corypha macropoda, Calophyllum spp., *Hopea helferi, Myristica andamanica, Uvaria andamanica,* and wild *Oryza* spp. are some of the endangered plants recorded from Andaman and Nicobar Islands.

CONSERVATION OF PRIMITIVE CULTIVARS

Many rare and primitive cultivars of cereals, millets, pseudocereals, pulses, and vegetables, which may already have disappeared in other parts of the world, can still be found grown by some tribes especially those living in inaccessible areas of the Himalaya or the Ghats. The primitive cultivars and wild relatives of crop plants preserved by the tribals may contain very rare and precious gene pools.

It is a common observation that the tribals who still live in undisturbed forest areas and have traditional food habits (eating a large variety of seasonal foods that they get from the forests) usually are quite healthy and free from many diseases. But most of the tribals today are deprived of their traditional foods because of depletion of forest resources and destruction of forest areas. These tribals suffer malnutrition and are susceptible to many diseases.

The nutritional analysis of certain pseudocereals (*Amaranthus polygamus* and *Fagopyrum esculentum*) traditionally eaten by the tribal and hill communities of high Himalayan areas showed that they are exceptionally rich in high quality protein. The nutritive value of these pseudocereals is found to be equal to that of casein. Leafy vegetables such as *Lamium albus* used by the tribals of Gurez valley of Kashmir are rich in minerals and proteins (20% to 26%). But due to the change in food habits, the younger generations are discarding these high nutritive plants and so suffer from malnutrition.

The seeds of *Cicer songaricum*, a wild plant growing in Ladakh area, contain abundant protein and phospholipids, also about 1% lecithin, equivalent to that present in brag soybean variety. Lecithin is an important product used as viscosity reducer, emulsifier, and wetting agent. It is in great demand for use in pharmaceuticals, cosmetics, and food industries. "Gabe muth", local variety of soybean found in the hills of Kashmir, is rich in lecithin.

Biological screening and phytochemical analysis of medicinal plants are warranted not only for discovery of new therapeutic agents but also for the discovery of new sources of economic materials and precursors for the synthesis of complex and important chemicals. Plant species, viz., *Canarium euphyllum, C. manii* (collected from Andaman forests), *Paeonia obovata* (from Western Ghats), and *Euphorbia acaulis* (from Madhya Pradesh) seem to be effective against rheumatoid arthritis and inflammation. *Adina cordifolia* and *Andrographis paniculata* (from Madhya Pradesh) are hepatoprotective and immunostimulant. Hepatoprotective and antifertility activities have been observed in compounds isolated from *Wedelia calendulacea* and *Kunstleria keralensis,* respectively. *Trichopus zeylanicus* from Agasthyar hills of Western Ghats was found to have anti-fatigue and immunomodulating properties (Pushpangadan, 1995).

ETHNOZOOLOGY

Ethnozoological studies in tribal-dominated areas in Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Gujarat, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Orissa, Rajasthan, Tamil Nadu, and West Bengal were completed by the Zoological Survey of India up to 1988. Some important findings from this study are summarized here.

The tribals use various wild and domesticated animals for food, drugs, game, and religious purposes. Interesting but lesser known uses of many birds and animals for food, medicine, and ornamental and religious rituals were recorded.

The meat of wild animals and birds used to be the principal source of protein for these people. Over 100 animals (including birds) were found to serve as useful sources of food to the tribals. Generally, the tribals are not very selective in hunting of animals except for those animals related to religious belief, folklore or myths, which vary widely from one tribe to another. On the other hand, some common animals such as wild boar, chital, sambar, cow, monkey, tortoise, frog, crab, prawn, insects, and molluscs are in great demand. The population declines of some of these animals have been caused by overhunting.

The tribal communities use a wide variety of medicines derived from invertebrate and vertebrate animals.

About 76 species of animals have served as vital sources of tribal medicine. Of these, 16 are invertebrates (insects, crustaceans, arachnids, molluscs) and 60 are vertebrates. The latter include six species of Pisces, one of Amphibia, nine of Reptilia, 16 of Aves, and 29 of Mammalia. The invertebrates are generally consumed as a whole animal. In case of vertebrates, the body parts, tissues, exoskeletons, flesh, blood, fat, bones, or other parts are used. Animal products such as honey, eggs, milk, spider net, urine, and faeces are valuable in curing some diseases. Some diseases known to be cured with animal drugs include tuberculosis, rheumatic and joint pain, asthma, piles, pneumonia, night blindness, impotency, paralysis, weakness, cholera, and body ache.

Body parts of various animals are used by tribals for a variety of domestic purposes. Dry shells of *Unio* for scraping, hairs of bear and horse for making ropes, camel hair for painting brush, coral for musical instruments, buffalo horns for making buttons and combs, and elephant teeth for making bangles are common practices among most tribes. Animal carcasses and cattle droppings serve as manure in crop fields. The tribals keep peacock, pigeon, parrot, mongoose, rabbit, and hare as pets. Fishing is an important vocation as well as hobby, in which earthworms, small fishes, frogs, insect larvae, flesh pieces are used as baits.

The tribals also worship some animals, e.g., cow, snake, and peacock.

The fat from more than 15 wild animals seems to be an effective medicine for curing various pains such as rheumatic pain. It is also applied externally as a remedy for pain, impotency, skin burn, and paralysis. Flesh, blood, shell, feather, bile, liver, intestine, milk, excreta, urine, dung, egg, honey, leech, termites, flesh oil, musk, antler, ghee, yolk, spider net, and fish scale have been found to have medicinal properties. The largest number of derivatives of a single species of bird is the hen's egg having 36 applications in curing a variety of diseases, followed by the bird peacock with 22 applications mostly related to stomach complaints, body ache, smallpox, chickenpox, and whooping cough. Many of the animal drugs used by tribals need to be analyzed scientifically for potential benefits to non-tribal people (Pushpangadan, 1995).

IMPACT OF TRIBAL LIFE ON LOCAL FAUNA

The tribal people look for local animals for food and medicine. They hunt them, particularly in forests. This imposes hunting pressure on these, which declines their populations. For example, in the Chhota Nagpur area in Bihar, the populations of blue bull, chital, sambar, parrot, and pigeon are heavily hunted. On the other hand, certain animals remain almost untouched due to religious beliefs. The enforcement of the Wildlife Act is somehow saving some animals from the grip of tribal population, hunters, and poachers.

The tribal relationships with fauna can be classified into different categories of organisms: prey (many animals), predators (tigers, lions, crocodiles), parasites (helminths, malarial parasites), pets (dogs, cats, birds), inquilines (scorpions, cockroaches, lizards, mice in the house), opportunists (lizards, squirrels, birds in the gardens), and pests (insects, molluscs, birds on crops). The tribal people are primarily predators but they are also preyed upon by other animals (Pushpangadan, 1995).

HUMAN ECOLOGY IN LADAKH

One good example of simple, traditional-living people is seen in the Ladakh area which is a high-altitude desert region that forms the western extension of the Tibetan (trans-Himalayan) plateau in India. Its high altitude (Ladakh's capital, Leh, is at 3534 metres) produces hypoxic conditions, high levels of solar radiation, and dramatic seasonality in temperature in a state of well-being and harmonious balance with the environment, as social institutions such as polyandry constrain fertility to keep the population size in check relative to constrained resources. Wiley (1997) has shown that the health of Ladakhi reproductive women and infants is compromised by both natural and social factors. Since reproductive health is crucial to the production of future generations, mortality may have a major role in constraining population growth in Ladakh, and may be due to the limited biological history that Ladakhis have in this high-altitude region. This may also help us understand Ladakhi patterns in relation to those observed elsewhere, in the Andes for instance (Wiley, 1997).

In Ladakh, subsistence agriculture is possible only through strict regulation of scarce or inaccessible water resources and high inputs of human labour. Braving all these harsh conditions, the human population there has managed fairly well to sustain itself. One interesting characteristic feature of Ladakh is a recurring celebration of traditional lifestyles as eminently sustainable and a feeling of peace, contentment, and even joy exhibited by the Ladakhi people in the face of highly stressful conditions (Norberg-Hodge, 1991; Crook and Osmaston, 1994). The Ladakhis have carefully managed their productive and reproductive systems and an expansive social and ritual life based on Tibetan Buddhist precepts where traditional forms of subsistence and social life make up a closely integrated system that is both highly productive and sustainable (Osmaston, 1994). This system is well suited to a finely-tuned and harmonious equilibrium between population, culture, and environment. There is a delicate balance between the number of people and the limited resources. Social mechanisms especially polyandry, regulating population growth, are central to the long-term success of Ladakhi lifestyles (Rizvi, 1983; Norberg-Hodge, 1981; Crook and Crook, 1994). Polyandry allows for only one reproductive female per generation in each household, thereby reducing overall population growth. It has been argued that polyandry also accounts for the relatively high status of women in Ladakh (Rizvi, 1983). Monastic Buddhism as an institution draws many males (and a few females) into a celibate religious life, thereby further reducing the size of the reproductive pool of adults.

Overall, the population density of Ladakh is just over one person/km^2. It is the least densely populated district of India. Only about 0.2% of the entire land area of Ladakh is inhabited or under cultivation due to the topography and limited access to water. Cultivation is possible only up to 4000 metres, above which nomadic or seasonally nomadic populations live with their livestock. The population is mostly rural and loosely organized in over 200 villages.

It is generally believed that the population—living traditionally—is quite healthy, and people live long and productive lives, generally uninhibited by serious infectious or degenerative diseases (Norboo and Yahya, 1988). It seems that Ladakhis subsist on an adequate caloric and protein base, with a diet heavily reliant on barley and supplemented with seasonally available vegetables and dairy products. However, deficiency anaemia is widespread, being particularly problematic under hypoxic conditions because iron mediates the body's capacity to transport oxygen and also contributes to possible shortages of calcium and vitamins A and B_{12} (Stobdan, 1990). Some very common infectious diseases here are respiratory diseases, exacerbated by cold, aridity, hypoxia, and domestic pollution. Also, cardiovascular diseases are increasing as a consequence of changing dietary and activity patterns, especially in and around Leh (Norboo and Yahya, 1988).

BIRTH WEIGHT

Goldstein (1981) repudiated the exclusive role for low fertility in constraining population growth among Tibetan populations and drew greater attention to the role of infant and child mortality. Among Tibetans in high-altitude Nepal, he noted that 20% of newborns died in infancy, possibly as a result of hypoxia. A consistent negative relationship between birth weight and altitude has been reported by several workers in other areas (Beall, 1981; Yip, 1987), probably because of intrauterine growth retardation which may be the outcome of an exaggerated hypoxic intrauterine environment, as the mother has to supply the foetus with oxygen when her own oxygen transport system is under stress from living in a hypoxic environment. Birth weight is also a strong predictor of infant mortality, particularly during the neonatal period (0–28 days).

Wiley (1997) reported that the average birth weight in Ladakh (2745 g) is lower than the average birth weight of Andean newborns at equivalent altitudes by 300–400 g and, somewhat surprisingly, by 500 g than Tibetan newborns in Lhasa. Over 50% of newborns in Ladakh weighed less than the mean. Birth weight was a significant predictor of mortality up to 28 days and 90 days, but not at 6 months or one year. Some factors that affect infant mortality in Ladakh are outlined in Fig. 2.2.

Population variation in newborn size has been demonstrated both within and between racial, ethnic, and socio-economic groups (Meredith, 1970). Such differences reflect various sources, e.g., genetic, nutritional, and developmental, all of which influence the resources available to the foetus. Smaller average size of newborns in high-altitude populations has been noted. Infants born at a high altitude have lower birth weights, on

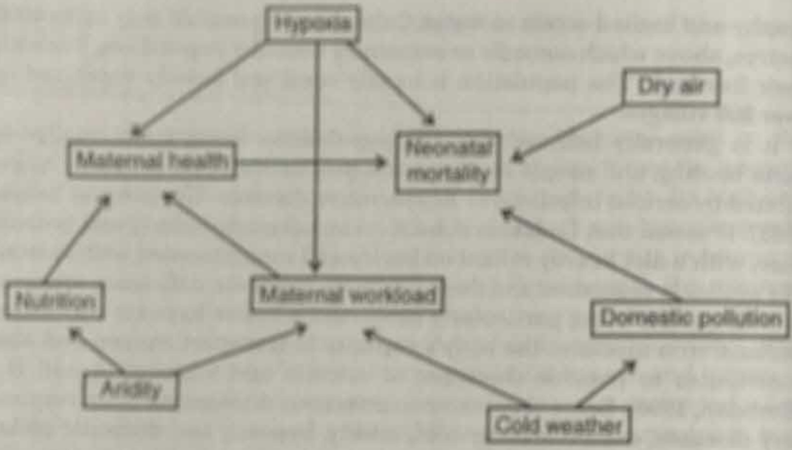


Fig. 2.2 Ecologically-mediated determinants of high infant mortality in Ladakh.

average, than their low-altitude counterparts (Wiley, 1994; Yip, 1987), and mothers who are native to high-altitude regions have given birth to larger infants than recent migrants. The cause of reduced neonatal size at high altitude is thought to be related to hypoxic conditions in utero that constrain foetal growth (Wiley, 1994).

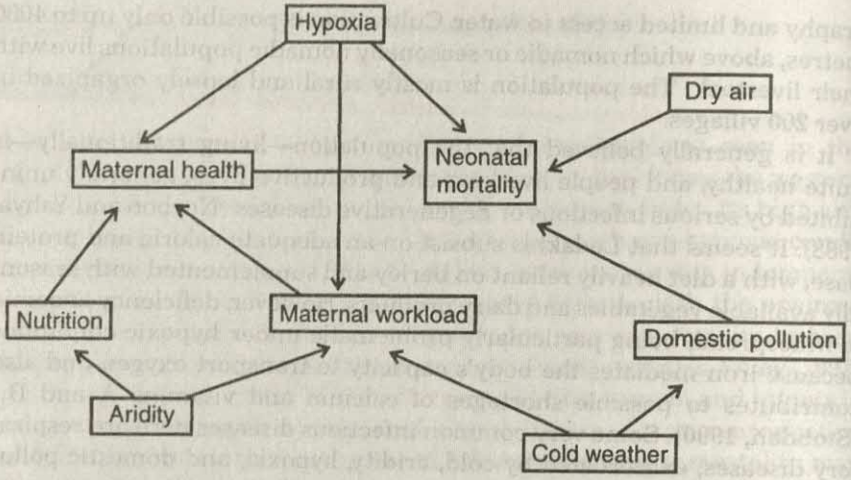
There is an intimate relationship between low birth weight and increased mortality risk, and various determinants of low birth weight can predispose a newborn infant to differential risks of morbidity and mortality. If it is recognized that both the selection pressures and the mechanisms for adaptation vary with the nature and severity of the environmental stresses, then it becomes understandable that the best maternal predictors of pregnancy outcome in one population may not necessarily be the best predictors for another population living in a different environment (Wiley, 1994).

Since Ladakh is located within the temperate zone, it has an extreme seasonal variation in climate, which has an important role in shaping the seasonal pattern of morbidity and mortality in so far as it affects people's behaviour and the prevalence of risk factors. Seasonal factors here are important correlates of infant morbidity and mortality, with respiratory illnesses most frequent in general, especially in the non-summer months, while gastro-intestinal diseases tend to be largely confined to the summer months. In the summer, more people (tourists, traders) crowd into Ladakh, particularly into Leh, resulting in contamination of the water supply, and the Ladakhi people have more contact with this water during the summer. In the winter, families spend most of their time indoors in poorly-ventilated houses heated by coal, dung, and wood. Thus, there is a strong correlation between respiratory symptoms and indoor carbon monoxide inhalation in the winter months, being particularly pronounced among women (Norboo *et al.*, 1991). As women and infants are usually together, this suggests a route by which infants may be at risk of severe respiratory stress in the winter (Wiley, 1994).

The importance of seasonal factors in Ladakh is also highlighted by the observation of a positive correlation between the season of peak mortality risk and peak birth rate. Babies born in the spring have lower birth weights than those born in the summer or autumn which correlates well with the observed seasonal trends in mortality, since mortality fell in the same months that birth weight increased. The seasonal pattern of birth weight also corresponds to the dietary intake, with higher intakes usually in the summer and autumn when imported food becomes available (because of the opening of access roads into Ladakh) and when the local foods (vegetables, fruits, and barley) are gathered (Wiley, 1994).

Significant variation in birth weight between the Tibetan and Ladakhi samples was reported (see Wiley, 1994). Differences between Tibetans (in Tibet) and Ladakhis reflect variation in a range of socio-economic, nutritional, and genetic characteristics. Tibetans in Ladakh have larger infants than Ladakhis but their average birth weight of 2990 g is lower (200–300 g) than that of the Tibetans in Lhasa (Moore, 1990; Zamudio *et al.*, 1993). Birth weight differences between Tibetans in Tibet and Tibetans in Ladakh are probably due to socio-economic and nutritional circumstances. Tibetan women in Ladakh were found to be 4 cm shorter than those in Tibet (Zamudio *et al.*, 1993). This suggests chronic undernutrition during childhood among Tibetan women in Ladakh. The Tibetan women in Ladakh also had substantially lower haemoglobin readings during pregnancy, suggesting dietary differences between the two Tibetan populations (Wiley, 1994).

Interestingly, mean birth weight in the Sherpa sample, which is a Tibetan-derived population living in Nepal, was closer to the mean birth weight of Tibetans in Ladakh (2957 g and 2990 g, respectively), and closer to the Sherpa sample (mean = 3069 g) described by Smith (1993) than to the Tibetan sample described by Moore (1990) and Zamudio *et al.* (1993). This shows that there may exist important differences between populations at the core and at the peripheries of the Tibetan culture area, where there is likely to be more genetic and lifestyle heterogeneity (Wiley, 1994a).



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3

Environmental Concerns

INTRODUCTION

During the 1960s and 1970s, the term environment was used without much thought for its implications. It meant, quite simply, the biophysical habitat. This definition reflected two centuries of western religious and cultural assumptions about the role of humans in the world. Human life was seen as fundamentally different from, superior to, and in charge of the rest of the biosphere. There were additional refinements to this world-view, reflecting a hierarchy of rank that placed men above women, women above children, mammals above reptiles, and Europeans above other races.

The term environment then, at first quite unconsciously, embodied this world-view of a human species set apart from its living habitat; the concept of nature involves a similar perspective though it carries a more romantic or emotional connotation. The 1980s saw the emergence of some cracks in this world-view. Increasingly, the perceived gulf between ourselves and everything else is disappearing. We now see ourselves inside and a part of the biosphere, not apart from it. This view, though new in western culture, reflects the perspectives of many other societies, such as the indigenous peoples of North America. We no longer see ourselves as set apart; many of us want cultural, social, and sometimes economic concerns to be encompassed in discussions about the environment. Environment may be defined broadly to include biophysical, socio-economic, spiritual, and cultural elements and their interactions (see Jacobs and Munro, 1988).

Ongoing crises in both the ecological basis for survival and in the social and economic order may be recognized as the initiating factors that demand change in the world and in our ideas about it. But there has been a forced conjoining of these two starting points of analysis into what we might call a unified theory of sustainable development, because, by the mid-1980s, it had become amply clear that these things are related in the physical world. Poverty and injustice are causes of stress to ecosystems, and impoverished environments undercut health and socio-economic development. The world is truly a closed circle, and deep-seated problems in one area interact with everything else in the human environment. According to WCED (1987): "In essence, sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations." Sustainable development seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future. But it means that growing economies remain firmly attached to their ecological roots which are protected and nurtured so that they may support growth over the long term. Environmental protection is thus inherent in the concept of sustainable development, as is a focus on the sources of environmental problems rather than the symptoms (WCED, 1987).

Environmental assessment (EA) is basically a process of analysis and criticism rather than a creative process. It does not generate solutions; it sets limitations or requirements on what can be done. Environmental impact assessment (EIA) processes define the rules, in the same way that traditional forms shape what a poet must do to write a sonnet. Similarly, the ability to synthesize, to envision, and to design is not particularly fostered by assessment procedures, but at least EIA processes should be monitored to make sure that they do not penalize creative solutions.

Another limitation comes from the issue of trade in the context of sustainable development. The touchstone often used is present and future human needs and aspirations. While some understanding of anthropogenic environmental stress and its relation to sustainability has been developing in the last decade, there is no corresponding understanding of sustainable economic patterns.

PEOPLE/ENVIRONMENT INTERFACE

People have been interacting with their environments over millennia in various ways, some sustainable over very long periods, some not. Some traditional agricultural technologies, at the low intensities prevailing then, would have increased biological diversity. Many traditional technologies, at the level employed, included biodiversity-conserving strategies as a part of the process of farming. Technology today, on the other hand, is sometimes viewed as a leading culprit in the process of biodiversity loss. Modern agricultural technologies override nature, albeit only locally and temporarily. Quite often, a technology itself is not a problem but it can become a problem if we use or apply it foolishly. In wise hands, technology can be a useful tool for improving the well-being of humanity.

Use of synthetic fertilizers reduces the constraints of depending on nitrogen-fixing and other soil microorganisms that assist in nutrient uptake—microorganisms that have been supported by traditional agricultural practices. But in the process of removing the constraints, these natural properties of ecosystems are lost, while the nitrogen and phosphate pollution affects groundwater aquifers and surface waters. Modern crop breeding has produced highly productive varieties of rice, wheat, corn, and other grains, but these varieties depend on irrigation, fertilization, pesticide technologies, and expansive monocultures, and so involve substantial environmental costs. Novel technologies that work *with* natural processes rather than overriding them are badly needed.

The unsustainability of civilized societies stems from the development based on fossil hydrocarbons which has allowed individuals to control their immediate environments in the short run while shifting environmental impacts to broader publics and longer time frames.

Environmental concerns are now at or near the top of the international political agendas. Several reports emphasize the urgency and importance of achieving sustainable forms of development, and identify the scientific, technological, and institutional changes that will be necessary to reach that goal.

Environmental assessment, in this context, is one of the keys to achieving sustainable development. This process is widely employed to integrate ecological and social considerations into development planning and control. It also suffers from certain deficiencies.

Recent experience with environmental assessments can help sharpen thinking on the enabling conditions of sustainable development.

The driving force behind the search for sustainable development, and the means to achieve it, is a deepening and pervasive sense of environmental crisis. At both the global and national levels, the nature of the current environment/development linkage is well documented.

A biohistory of the human tenure on earth shows a massive recent expansion in the nature, magnitude, and scale of environmental impacts (Boyden, 1987). The long-term changes that now concern us are regional and global, encompassing the effects of the overall pattern of economic activity on the biosphere and atmosphere. At this level, two key examples of environmental change include

(1) global warming and loss of stratospheric ozone, both representing the cumulative effects of intensive, energy-based industrial development on the biogeochemical cycles that constitute the basic life-support systems on earth; and

(2) continued reduction in biological diversity (i.e., of living species that maintain ecosystems in a productive and resilient state), which is now seen as an equal or even greater threat to the future of mankind than climate change (Wilson and Peter, 1988).

These and other trends and changes are interrelated through complex and often reinforcing chains of cause and effect. Land clearance and habitat damage in tropical forests, for example, are having significant effects on both global warming and loss of biological diversity. The increased temperature and precipitation effects associated with global warming are expected to become more pronounced with increasing latitude. While regional changes are difficult to predict on the basis of current models, the socio-economic dislocations associated with impacts on land use, agriculture, resource production, and human settlement threaten to be profound (see Jacobs and Sadler, 1991). Overexploitation of natural resources in the Third World is the price of poverty rather than of prosperity.

Thousands of fishing villages, where many villagers are fishermen, are located along seacoasts. With the coastal and marine ecosystems being subjected to various stresses that harm them, the cycle of poverty has driven deeper into most fishing villages, making judicious use of the ecosystems' remaining resources tenuous. Each of these villages may be viewed as being made up of three subsystems: the production system, the natural system, and the social system. The three subsystems add up to a human ecosystem that is invariably complex, involving socio-ecologic interactions of concessions on one end and conflicts on the other. The natural system is a web of physical and biological environments from which the production system draws its resources to process goods or services, and with which the social system ascribes the mechanism of distributing resources, identifying roles, and managing flows and feedbacks. Out of these three subsystems, the social system is the most difficult to manage, develop, and plan for sustaining the other systems.

The strategic importance of the mangrove forests, sea grasses, and coral reefs needs to be highlighted as also the development of local initiatives in declaring marine areas as reserves or parks and cooperative adoption of a measure to restructure the indigenous social system in any fishing village.

The impacts of human activity on the global environment can be seen in the substantial transformations of the earth's land cover that reflect the use of land-based resources and that have profound implications for the biosphere and for human well-being. Their causes and consequences are of concern to all.

CLIMATE CHANGE

Human intervention in natural cycles and processes is disturbing the climatic and ecological balance at a rate much greater than anything experienced in the past. In the build up of carbon dioxide to current levels, this is outside the known range of natural fluctuation. The estimated rise in mean surface temperature during the next 5 decades is between 1.5°C and 4.5°C. At the top end of the scale, this would be the highest figure during the last 150,000 years. Such changes seem inevitable if we continue along present pathways of development.

Our biosphere and geosphere are interdependent, mutually-regulating systems, and urban-industrial man is the main source of global disruption and potential malfunction.

Sustainable development (Fig. 3.1) not only involves coming to terms with resource limits but also meeting the needs of present and future generations. Much emphasis is given to the role of conservation in improving the lot of the rural poor in Third World countries. There has been a recent shift from a rearguard defence of endangered species to a strategic initiative to improve human welfare and halt the deterioration of the biosphere.

The effects of increasing greenhouse emissions during the past few

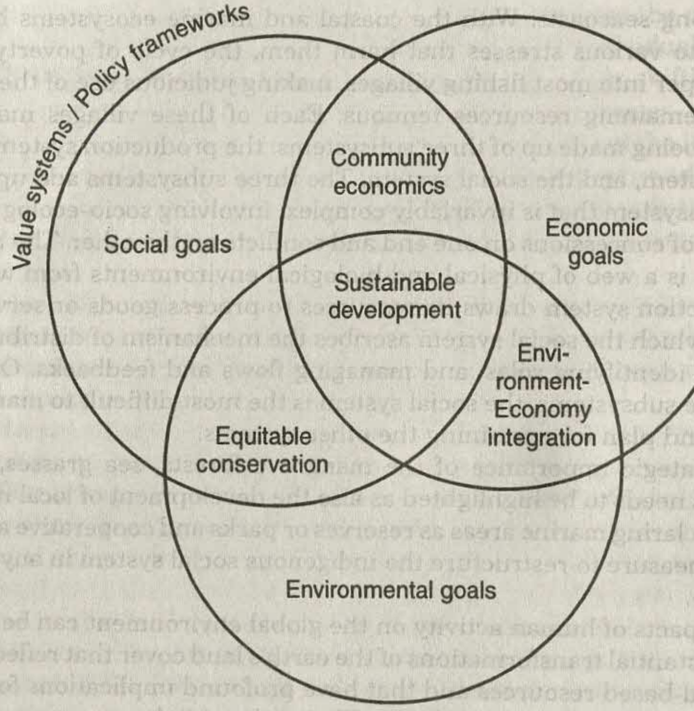

Fig. 3.1 Systems perspective on sustainable development (after Jacobs and Sadler, 1991).

decades are already being felt now. Glaciers are melting at accelerating rates. Icebergs are breaking off Antarctica. Warming has been detected in the deep oceans. Diseases are spreading as mosquitoes can now be found in areas that only a few years ago were too cold to allow their survival. The tundra which absorbed greenhouse gases for millennia is now thawing and releasing them (Gelbspan, 1997). This first level of consequences is a succession of very extreme weather events. And if one thinks of what's happened since only the beginning of 1997 (hail- and rainstorms in the Pacific Northwest, the worst floods in 3 decades in Bolivia that destroyed half their crops, the worst flooding in a century in Czechoslovakia and Poland), there are droughts spreading where there never were before. These are perhaps the early warning signs of global warming and they are going to worsen in the coming years until we deal with this problem now.

There is a general erroneous impression among many lay people that global warming is a controversial and uncertain issue which the scientific community is not agreed upon. Actually, in late 1995, a consensus of 2000 scientists reporting to the UN concluded that climate change is already happening, that it is due to our burning of coal and oil, and that there really is little scientific doubt about this. This means that in the long run we must change our fuel sources but that means, inevitably and invariably, the ultimate demise of the fossil fuel industry. So, as part of the response to this information, this industry has been waging a very pervasive, effective, and expensive campaign of deception and disinformation which has basically created some doubt in the public mind about this issue largely through inserting costly advertisements in the media. The huge amounts of money that corporate sponsors have spent on buying media space, on mailing to journalists, on buying platforms and public appearances has confused the public. There really is no debate about the science at all.

Many governments are already going in for renewable technologies. There is a market right now of two billion households in the rural Third World, where solar energy is economically viable. For some northern cities, fuel cells and hydrogen gas can be very worthwhile, and in some places wind farms. All these renewables can provide all of the energy that we need.

SUSTAINABLE DEVELOPMENT

What is needed is a clearer definition of the relationship between the themes of sustainable development and of peace, justice, and security, and between the conservation movement and the interests of indigenous and other peoples whose livelihood and culture are directly related to land, resources, and environment.

An operational perspective on sustainable development involving a move beyond definition may be achieved by reorganizing and augmenting the goals, principles, and criteria that are established or implied by the themes of sustainability. Sustainable development is oriented toward achieving environmental, economic, and social priorities. Accordingly, three basic goals might be (1) meeting basic human needs for material welfare; (2) maintaining ecological integrity of natural systems; and (3) providing for equity, social justice, and choice of lifestyle (Jacobs and Munro, 1988). Sustainable development may best be thought of as a commonwealth of goals and of the value systems and policy concepts. Some noteworthy points about this systems perspective on sustainable development are the following:

(1) Perhaps a conventional approach to development, often narrowly based on orthodox economics, ought to be replaced by a broader, more integrated framework for analysis and choice.

(2) Sustainable development incorporates, for example, goals that cannot be maximized simultaneously. Quite different intellectual models and modes of judgement and valuation can be seen juxtaposed in Figs. 3.1 to 3.3. The cross-cutting or linking themes also encompass distinct orientations. For example, the contemporary discussion of environment-economy integration tends to focus on government and industry reorganization and partnership and to overlook the concerns of distributive justice that are central in community economics and conservation with eq-

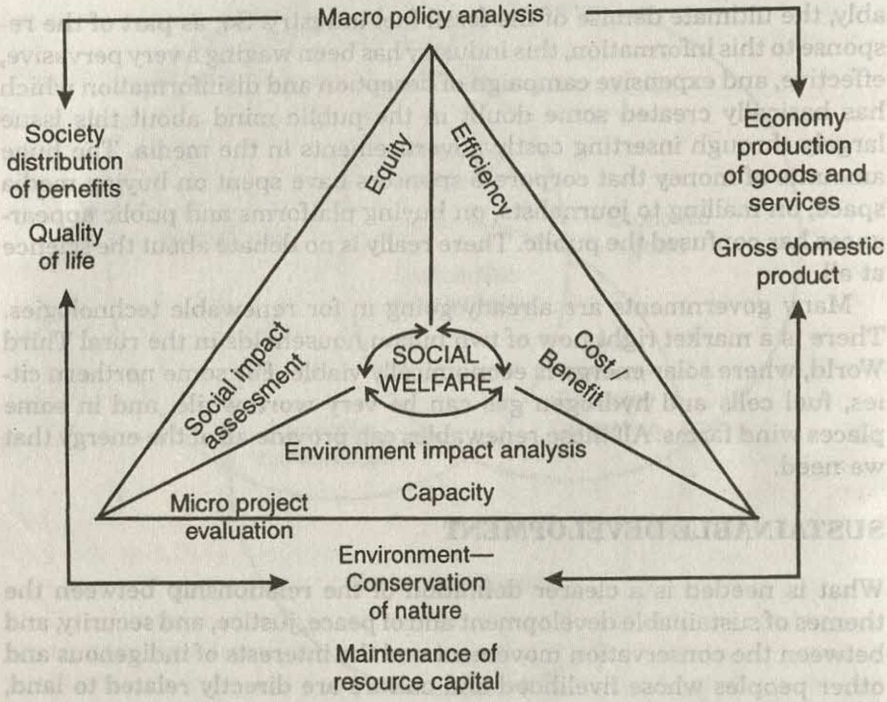

Fig. 3.2 Decision-making for sustainable development: criteria and components (after Jacobs and Sadler, 1991).

uity (Jacobs and Sadler, 1991).

(3) The achievement of sustainability requires trade off within competing and contingent priorities. This involves a proper balancing of values and interests. Sustainable development includes meeting all of the various goals at some minimum level, and no goal should be consistently promoted or discounted at the expense of the others.

(4) The continued functioning of natural systems represents the enabling condition of sustainable development. Environmental limits are finite and once crossed, the resulting changes in ecological resilience, resource productivity, and assimilative capacity may be irreversible.

A useful concept for formally organizing the interpretation of sustainable development is that of the *carrying capacity*. This concept may be traced back to the time of Malthus. More recently, economists and statisticians have started treating the environment as natural capital, and also devising accounting systems that measure its depletion. In this formulation, sustainable development may be viewed as constancy of resource stocks and the ecological processes necessary to maintain their productive (source) and assimilative (sink) functions.

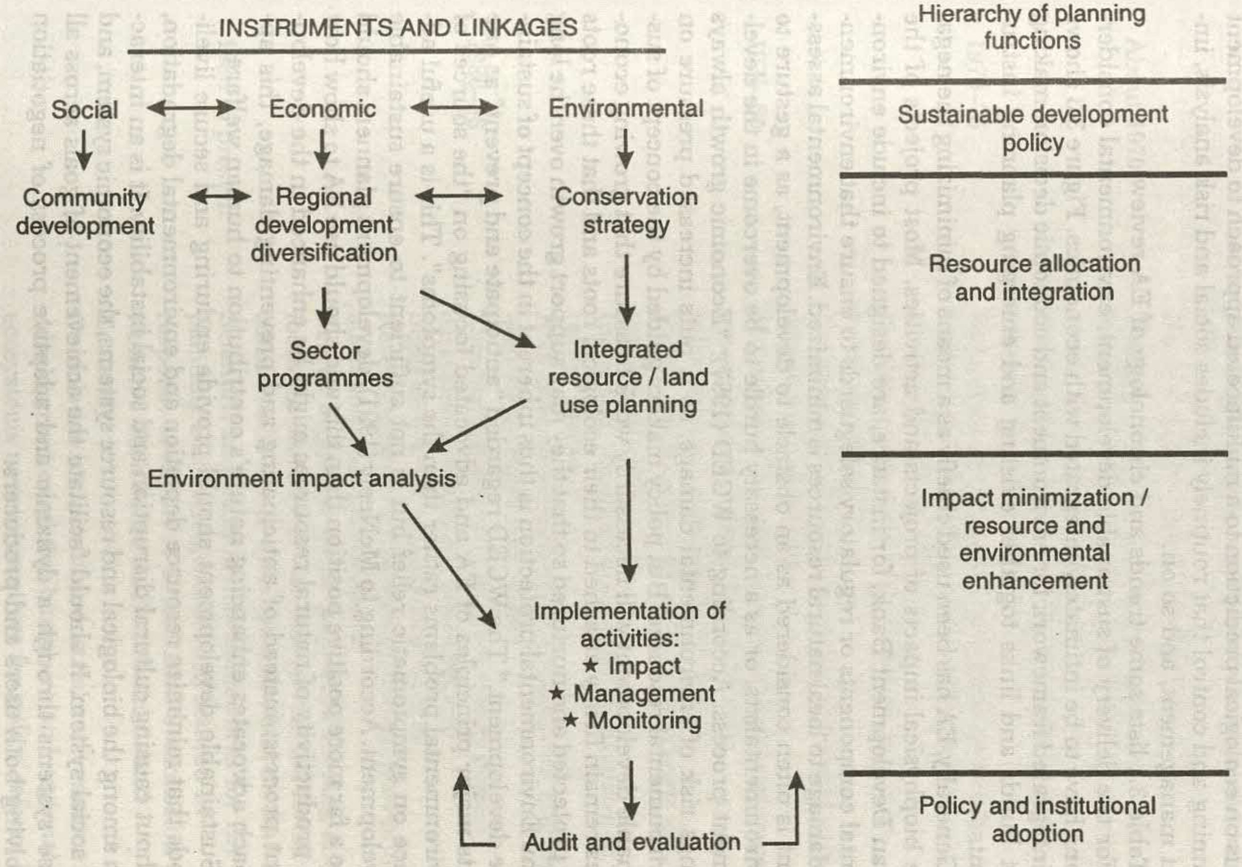
INSTRUMENTS AND LINKAGES
Social
Economic
Environmental
Community development
Regional development diversification
Conservation strategy
Sector programmes
Integrated resource / land use planning
Environment impact analysis
Implementation of activities:
★ Impact
★ Management
★ Monitoring
Audit and evaluation
Hierarchy of planning functions
Sustainable development policy
Resource allocation and integration
Impact minimization / resource and environmental enhancement
Policy and institutional adoption

Fig. 3.3 Integrated approach of environment and development decision-making (after Jacobs and Sadler, 1991).

ENVIRONMENTAL ASSESSMENT

Environmental assessment has recently seen a shift from a single-purpose focus on ecological prediction to a multifaceted approach to development planning and control that routinely includes social and risk analysis, impact management, and so on.

Table 3.1 lists some trends and chronology of EA review.

For the delivery of sustainable development, environmental considerations have to be intimately integrated with economics. Figure 3.3 shows an integrated framework for environment and economic decision-making that builds and links together existing and emerging planning instruments.

Generally, EA has been used chiefly as a means of minimizing the negative biophysical impacts of projects and activities. Most projects of the Asian Development Bank, for instance, are designed to include environmental components or regulatory safeguards to ensure that environmental damage to local natural resources is minimized. Environmental assessment is often considered as an obstacle to development, as a gesture to environmentalists, or as a necessary hurdle to be overcome in the development process. According to WCED (1987): "Economic growth always brings risk of environmental damage, as it puts increased pressure on environmental resource. But policy makers guided by the concept of sustainable development will necessarily work to assure that growing economies remain firmly attached to their ecological roots and that these roots are protected and nurtured so that they may support growth over the long term. Environmental protection is thus inherent in the concept of sustainable development." The WCED regarded "anticipate and prevent" as one of its major principles of EA and advocated focusing on "the sources of environmental problems rather than the symptoms". This is a useful advance on symptomatic relief but is not sufficient to ensure sustainable development. According to McNeely (1991), development planners should take a far more positive position than this and should use EA to show how the productivity of natural resources might be enhanced in the development process; instead of anticipating and preventing damage, this approach advocates enhancing nature's contribution to human welfare.

Sustainable development should provide enduring and secure livelihoods that minimize resource depletion and environmental degradation, without causing cultural disruption and social instability. It is an interaction among the biological and resource systems, the economic system, and the social system. It should facilitate the achievement of goals across all these systems through a dynamic and adaptive process of negotiation involving both users and producers.

Though the relative contribution of each may vary from place to place and time to time, sustainable development will always include the following interrelated components:

(1) an economic dimension, dealing with the creation of wealth and

Table 3.1 Some trends in environmental assessment and review

Approximate date	Innovations in technique and procedure
Pre-1970	Analytical techniques largely confined to economic and engineering feasibility studies Narrow emphasis on efficiency criteria and safety of life and property No real opportunity for public review
About 1970	Multiple objective benefit-cost analysis Emphasis on systematic accounting of gains and losses and their distribution Environmental and social consequences not formally incorporated
1970–75	Environmental impact assessment primarily focused on description and 'prediction' of ecological/land use change Formal opportunities for public scrutiny and review established Emphasis on accountability and control of project design and mitigation
1975–80	Multidimensional EA incorporating social impact assessment of changes in community infrastructure, services, and lifestyle Public participation becomes integral part of project planning Increasing emphasis on project justification in review process Risk analysis of hazardous facilities and unproven technology in frontier areas
1980–86	Establishing better linkages between impact assessment and policy planning and implementation management phases Research focus on effects monitoring, post-project audit and process evaluation Search begins for more disciplined scoping and focusing procedures and less protracted forms of consultation based on negotiation and mediation
1986 to present	Scientific and institutional frameworks for EA planning and management restructured in response to report of Brundtland Commission and National Task Force on Environment and Economy Cumulative impacts of industrial and resource development on global biosphere and regional ecosystems new imperatives for policy reform and process adaptation International aid agencies incorporate EA procedures into development planning and project appraisal

improved conditions of material life;

(2) a social component, measured as well-being in nutrition, health, education, and housing;

(3) a political dimension, pointing to such values as human rights, political freedom, security, participation, and some form of self-determination;

(4) a cultural dimension, because cultures confer identity and self-worth to people; and

(5) an ecological component, recognizing the primacy of conserving the life-giving natural resources and processes on which all progress depends (McNeely, 1987, 1991).

The first two conditions have usually tended to be emphasized by development projects, whereas only the fifth one has attracted notice for EA. The political and cultural dimensions have by and large been ignored in most cases.

Environmental assessment can analyze the interactions among economic development, social and cultural factors, and environmental resources. Based on such analysis, environmental management options can be developed. Environmental assessment needs to be far more proactive than reactive if it is to contribute significantly to sustainable development.

Environmental assessment tends to look at only a narrow spectrum of the issues that need assessing. It is almost invariably carried out too late, and ends too soon.

Environmental assessment should look at objectives as well as impacts. Rather than being confined to project interventions, it should deal with the major value decisions on the objectives of development, which are addressed before choices are made between possible projects (McNeely, 1991).

There exists a great potential for applying EA to the actual formulation of land use policies. This is a proactive as opposed to reactive role of EIA in a land use decision-making framework. Regional studies have been made in some countries (e.g., UK) to identify sites in anticipation of demand for the optimum location of major development activities, in which economic, social, and environmental factors are all assessed, and evaluations made of optimum strategies for the restoration of derelict land. Far less successful has been the application of EIA to the actual formulation of land use plans, where attempts have been made to show that plans are, in effect, packets of policies comprising discrete project elements which could therefore be subjected to EA. In the context of land use planning, other approaches that might be worth exploring as a framework include land suitability assessment, agroecological zoning, and life zone classifications.

BUSINESS RESPONSIBILITY FOR SUSTAINABLE DEVELOPMENT

In the last few years, big business houses have become interested and associated ever more closely with the goal of promoting sustainable development. There are signs that a new corporate ethic is in the making, encouraging business executives to minimize the environmental impacts of their operations rather than to regard the environment as an externality. Although large firms in developing countries generally lag far behind their counterparts in richer nations in terms of corporate environmental management, it is clear that stricter environmental standards, cleaner technologies, and waste reduction practices are becoming more commonplace. And yet, there is some doubt as to whether more ecoefficient resource management systems, and self-regulation are really contributing anything worthwhile to sustainable development, particularly in developing countries.

There are dangers in generalizing about corporate behaviour. Whereas some progress has occurred in certain industrial sectors, in others, changes have been quite minimal. In some countries and sectors, transnational corporations, as well as firms producing for export markets, are performing better than others in terms of improving environmental management systems. Large companies are usually in a better position to introduce cleaner technologies.

In Central America, Malaysia, and Mexico, the record of business in the field of corporate environmental management appears to have been fairly dismal (see UNRISD, 1998) and there is a wide gap that separates corporate rhetoric and actual performance.

Besides the problem of getting the policies and prices right, it is crucial to understand how to work constructively with business. Firms are limited in what they can take on at any one time in terms of environmental and social responsibility. While there is much goodwill among corporate executives, some remain unconvinced of the need for major change and others may lack the know-how to improve environmental management systems in a cost-effective way. Accordingly, feasible priorities and targets need to be set and practical information and training are essential. In many situations, it is wiser to go in for an incremental approach, focusing initially on more obvious 'win-win' solutions that will afford environmental management positive spin-offs in terms of profits, company image, and market share. In addition, corporate executives need positive feedback on what they are doing right, as opposed to constant criticism (UNRISD, 1998).

TOURISM IN DEVELOPING COUNTRIES

Studies on the nature, magnitude, and impact of domestic and regional tourism in different socio-economic and environmental contexts, and on diverse social groups in developing countries are attracting serious notice. Concrete attempts to formulate policy for coping with national and regional mass tourism are being evaluated because national and regional tourism involves large numbers of people—thereby challenging the practice of sustainable, ecological or 'managed' tourism. There is need to offset the more negative impacts of national and regional mass tourism through appropriate information and awareness campaigns, and through tourism policies that reflect the needs and interests of domestic and regional tourists—as well as their potential contribution to local employment and national output (UNRISD, 1998).

In Brazil, some negative impacts of tourism have been offset by actively integrating local communities into tourism development (Diegues, 1997; see UNRISD, 1998). In India, the growth of the domestic tourism sector has been found to create some tensions between urban lifestyles and village traditions, and certain trade-offs are involved in increasing economic revenue and promoting tourism policies that are culturally and environmentally friendly (Rao and Suresh, 1997).

Properly managed tourism can also aim toward more cross-cultural understanding, greater appreciation of the problems faced by other countries, greater homogenization of developing and developed worlds, less chance of war, more exchange of ideas, and better international cooperation. Ecotourism can go a long way in stimulating financial support from the developed countries for environmental protection in developing countries. Sustainable development can become a truly global phenomenon only when the people of diverse cultures understand each other much better than they do now.

THE POLITICAL-ECONOMIC CONTEXT

The twentieth century has seen a great expansion of science, technology, industrialization, and material production. Scientific rationality and technological efficiency have been the primary measures of social progress and the scientific approach succeeded in separating factual knowledge from values, and asserted the primacy of the former over the latter.

To judge from economic behaviour (see Fig. 3.4), public and society see the physical world and the biosphere mainly as a resource base to be exploited to satisfy the material needs and wants of man. Businessmen and technocrats are the heroes of the new age and the most prominent role models for youth. The competitive ethic of the free market economy provides the accepted standard for proving individual self-worth, with success measured in terms of conspicuous consumption and the accumulation of personal property.

Reductionist mechanistic science remains our dominant analytic mode. Consequently, society's prevailing ecological myth sees environment in terms of isolated, individual resources or, at best, as a mechanical construction that can be moulded to suit human will and purpose.

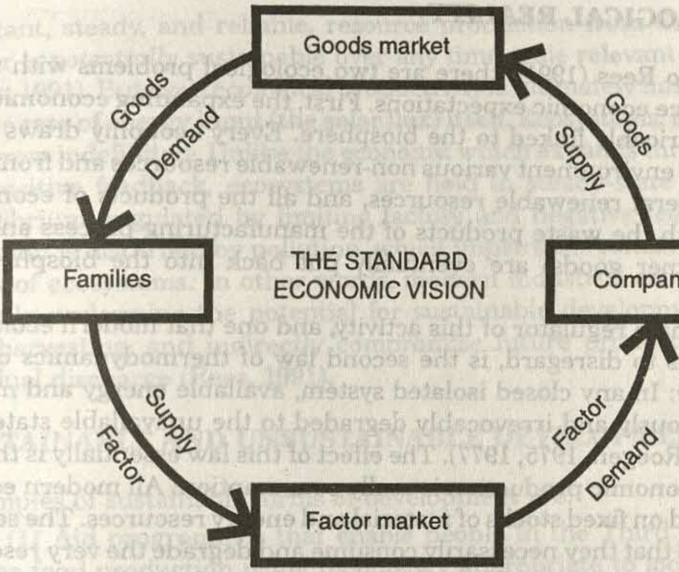

Fig. 3.4 Standard economic model. Money flows clockwise in payment for real things such as houses, food, and clothes. Factors are exemplified by land, labour, and capital.

Contemporary economics is also cast from the mechanical mould. The founders of the neoclassical school, impressed with the spectacular successes of Newtonian physics, strove to create economics as a sister science, "the mechanics of utility and self-interest" (Jevons, 1979). This mechanical analogue implies that economic process is "a self-sustaining circular flow between production and consumption within a completely closed system". In short, "complete reversibility is the general rule, just as in mechanics" (Georgescu-Roegen, 1975).

A corollary of this equilibrium theory is that the continuous exchange of material resources, and the unidirectional flow of free energy between the economic process and the material environment is of little, if any, importance with the neoclassical economics: resources are supplied not by nature but by human ingenuity. According to Solow (1974), the world can, in effect, get along without natural resources. Similarly, any damage to environmental processes caused by human activity is assumed to be inconsequential or, in any event, largely reversible.

Current socio-economic systems are driven by the positive feedback of exponential growth. This is apparent from a look at the business pages of any newspaper. The annual per cent increase in gross national product (GNP) is taken as every nation's primary indicator of national well-being. Rates below 3% are considered sluggish, and planners don't feel happy until growth in GNP approaches 4–5% per annum. It may be noted that 4% increase implies a doubling of economic activity in a mere 17 years (Rees, 1991)!

THE ECOLOGICAL REALITY

According to Rees (1991), there are two ecological problems with these commonplace economic expectations. First, the expanding economic system is inextricably linked to the biosphere. Every economy draws from the physical environment various non-renewable resources and from ecosystems several renewable resources, and all the products of economic activity (both the waste products of the manufacturing process and the final consumer goods) are eventually put back into the biosphere as wastes.

The ultimate regulator of this activity, and one that modern economic theory tends to disregard, is the second law of thermodynamics or the entropy law: In any closed isolated system, available energy and matter are continuously and irrevocably degraded to the unavailable state (see Georgescu-Roegen, 1975, 1977). The effect of this law essentially is that all so-called economic production is really consumption! All modern economies depend on fixed stocks of material and energy resources. The second law dictates that they necessarily consume and degrade the very resource base that sustains them. The substitution of one depleting resource for another can only be a stopgap measure on the way to scarcity. Even resource recycling has a net negative impact on remaining stocks of available energy and material. In short, all economic activity contributes to a constant increase in global net entropy (disorder) through the continuous dissipation of free energy and matter. Contrary to theoretical assumptions, there is no equilibrium of any sort in the material relationship between the economy and the environment (Rees, 1991). The global economy is really a closed system, and is little affected by world trade. Thermodynamic law sets an absolute limit on the material growth of the world economy. Thus, contrary to the implicit assumptions of neoclassical economics, sustainable development based on prevailing patterns of resource use may not even be theoretically conceivable.

The second ecological difficulty with the growth-dependent economy pertains to the functioning of ecosystems themselves. Like economic systems, ecosystems also depend on fixed stocks of material resources. However, the material resources of ecosystems are constantly being transformed and recycled throughout the system via food webs at the local level, and biogeochemical cycles on a global scale. In addition, evolution and succession in nature tend toward ever greater order and complexity. The material cycles and developmental trends of ecosystems appear at first glance to defy the thermodynamic law. Ecosystems seem to be inherently self-sustaining and self-organizing and therefore to contribute to a reduction in global net entropy. This is possible only because ecosystems, unlike economic systems, are driven, via photosynthesis, by the sun which is an *external* source of free energy.

Material recycling is therefore the source of all renewable resources used by the human economy. Moreover, since the flow of solar radiation is constant, steady, and reliable, resource production from the ecological sector is *potentially* sustainable over any time scale relevant to mankind (Rees, 1991). But even ecological productivity is ultimately limited, in part, by the rate of energy input (the solar flux) itself. Ecosystems, therefore, do not grow indefinitely. Unlike the economy, which expands through intrinsic positive feedback, ecosystems are held in steady-state or dynamic equilibrium, regulated by limiting factors and negative feedback. This situation is disturbed by pollution, which impairs the remaining productivity of ecosystems. In other words, modern industrial economies both directly undermine the potential for sustainable development through overharvesting, and indirectly compromise future production through residual discharge (Rees, 1991).

SUSTAINABLE AND UNSUSTAINABLE DEVELOPMENT

Examples of sustainable forms of development are:

(1) Aid programmes that enable people in the Third World to increase food production using technology appropriate to local ecological conditions.

(2) Development programmes that respect and enhance local adaptations to prevailing ecological conditions.

(3) No-tillage organic agriculture.

(4) Resource comanagement programmes with emphasis and priority on native subsistence requirements ahead of commercial or recreational demand.

(5) Development designed to displace non-renewable forms of energy with renewable solar-based forms.

(6) Community development that disfavours labour-displacing, land-destroying technological innovations and favours human and animal labour.

Examples of unsustainable development activities include:

(1) Aid programmes that facilitate the concentration of land ownership, undermine local staples production, and encourage cash cropping for export which is often required to earn money to repay the development loan.

(2) Introduction of technological innovation from the north temperate zone such as gasoline-powered machinery, irrigation schemes, and chemical fertilizers that may be ecologically inappropriate for arid, semi-arid, tropical, and subtropical ecosystems.

(3) Irrigation strategies that produce short-term gains and dependencies but eventually lead to destructive salination of the soil.

(4) Use of chemical fertilizers that produce short-term gains but lead eventually to loss of production due to soil acidification.

(5) Destruction of tropical rain forests for agricultural settlement in

laterite soil areas. In this instance, most of the essential nutrients, being contained in the tree biomass, are lost in logging or burning.

(6) Hydroelectric/irrigation projects that initially boost production and create dependencies but which fail when the reservoirs fill up with sediment often produced by unsustainable forestry or agricultural practices.

(7) Market-driven fisheries and forestry practices that have led to stock depletion and destruction of future productive capacity almost everywhere.

(8) The current type and levels of economic activity and technology producing continuous deterioration in key environmental quality indicators such as the build up of carbon dioxide, other greenhouse gases, and acid rain (Rees, 1991).

Many of the serious regional or global environmental problems such as disappearing forests, acid rain damage, thinning ozone layer, and rising carbon dioxide levels are the cumulative result of an array of expanding economic activities around the world. Some of these trends have the potential to inflict inestimable damage on large areas or even globally. This means that it is the whole present pattern of growth-driven economic development, not just some particular project or economic sector that is unsustainable. Such cumulative trends spell impending threats to survival and the appropriate response may require a reassessment of the values, beliefs, and assumptions upon which the near-universal growth model of economic well-being is founded. Minor adjustments at the level of improved environmental regulation and pollution control techniques are simply inadequate (see Rees, 1988, 1991). Whatever else may be required, environmental assessment will certainly have to break out of its current limited conceptual and practical boundaries if it is to make a significant contribution to cumulative assessment and the achievement of sustainable development in any reasonable form (Rees, 1991).

An understanding of carrying capacity provides a functional definition of sustainable development (see Borgstrom, 1973; Clark, 1973). In ecological terms, any level of development or economic activity that does not exceed the carrying capacity of a management region is sustainable. Conversely, ecosystems upon which the regional population is dependent are not sustainable in the long run. While this framework is conceptually simple, various factors make it difficult to put it in operation. For example, interregional flows and commercial trade in ecological goods and services obscure the immediate people/land relationship.

FRAMEWORK FOR REGIONAL ACTION

The following framework of regional action may be suggested for sustainable development:

(1) Assessment and monitoring of environment and sustainable development trends

(a) Publication of regional environmental and sustainable development reports

(b) Preparation of national reports or periodical communications on sustainable development

(c) Collation and development of major environmental indicators

(d) Development of national and regional environmental monitoring capabilities

(e) Encouragement of mutually supportive trade and environment issues

(f) Analysis of regional impacts of population growth and poverty on environment with special reference to least developed countries

(2) Ecosystem management and rehabilitation

(a) Support of desertification control

(b) Combating deforestation and land degradation

(c) Establishment and sound management of national parks and nature reserves, and biodiversity conservation

(d) Coastal zone management and protection of marine ecosystems through development of suitable management plans

(e) Protection of quality and supply of freshwater resources

(f) Environmentally-sound management of watershed/river systems and of atmospheric environment in the region

(g) Rehabilitation of other degraded ecosystems

(3) Development of policies, guidelines, and management tools

(a) Supporting national efforts to undertake risk and environmental impact assessments

(b) Research, development, and application of natural resource accounting

(c) Critical assessment and use of appropriate economic instruments (e.g., taxes and subsidies, pricing policies such as polluter pays principle (PPP), user pays principle (UPP), effluent charges, tradeable permits, property rights) to enhance national efforts towards environmentally-sound and -sustainable development

(d) Undertaking studies related to cost and benefits of resource flow and utilization, and system analysis and building appropriate models for sustainable development

(4) Strengthening institutional, legislative, and human resources development

(a) Supporting national efforts in strengthening environmental legislations with particular reference to economic instruments, environmental impact assessment, resource recovery, and pollution control

(b) Development of regional conventions and urging the countries to ratify and implement as appropriate, international conventions/treaties and protocols relating to the environment, in particular

- Convention on Biological Diversity, Convention on International Trade in Endangered Species of Wild Fauna and Flora, and Convention on Wetlands of International Importance Especially Waterfowl Habitat
- Basel Convention on Control of Transboundary Movements of Hazardous Wastes and Their Disposal
- United Nations Framework Convention on Climate Change
- Vienna Convention for Protection of Ozone Layer and Montreal Protocol on Substances that Deplete Ozone Layer

(c) Strengthening of national capabilities in emergency preparedness in response to natural and man-made environmental disasters

(5) Promotion of environmentally-sound technologies

(a) Setting up of appropriate environmental quality standards and transfer of pollution control technologies including clean technologies and environmental audit

(b) Promoting environmentally-sound management of toxic chemicals and hazardous wastes

(c) Promoting energy efficiency and energy conservation

(6) Promotion of environmental awareness, communication, and public participation in sustainable development activities

(a) Enhancement of environmental awareness through mass media

(b) Promotion of public participation in sustainable development activities including campaigns and awards

(c) Wide dissemination of results of case studies, especially on pollution prevention and environmental restoration

(d) Promotion of formal and non-formal environmental education

(7) Regional dimensions of global environmental issues

(a) Assessment of regional dimensions of global environmental issues such as climate change and associated sea level rise and ozone layer depletion

(b) Formulation of regional strategies on combating climate change and associated sea level rise and ozone layer depletion

(8) Financing

(a) Mobilizing additional domestic resources for implementing national environmental programmes of regional concern

(b) Exploration of innovative financing options for national and regional environmental programmes

POLITICAL ECOLOGY AND LANDSCAPE ECOLOGY

There are two popular theoretical perspectives that attempt to explain the relationships between human activity and environmental function and structure. Political ecology involves the integration of social and natural science from a social perspective. Landscape ecology involves the integration of social and natural sciences from natural perspectives. Although an integration of society and environment is critical to each, both are limited by their focus on one or the other. It is the interaction that needs to be highlighted. There should be strong interactions between economic, historical/cultural, political, and environmental processes and these interactions need to be understood in terms of differences in scale, time, and power (see Campbell and Olson, 1991; Maguire *et al.*, 1991). Spatial scale, organizational scale, and temporal dynamics are critical in representing such interactions. As the process of modelling social and environmental systems is influenced by much uncertainty, resulting largely from the complexity of the systems, new methods are needed to combine insights of different scientific and policy approaches and from different disciplines.

Because geographic information systems (GIS) facilitate the integration of spatial data from disparate sources through a variety of transformations, they may be effective tools for managing data. The GIS technology is better developed and is more commonly used for applications of environmental data than social data (see Maguire *et al.*, 1991).

Remotely sensed data provide spatially extensive data on land surface properties. Remote sensing provides data that are strongly skewed towards the natural environment, and can be an important complement to survey data. However, these data suffer from certain limitations of spatial and temporal resolutions. Some social data are just not suitable for spatial representations. For example, survey data are often representative of some regions, but are not good for mapping. Furthermore, the variables measured using survey data usually have a great deal of variation or are quantitative in nature, which means that interpolation is impossible.

As theoretical, methodological, and institutional issues that affect data integration are all sensitive to scale, various problems can emerge depending on the scale of analysis (whether global, national or local). Therefore, a hierarchical approach to data integration wherein environmentally-critical areas are identified at each scale is preferable (see Campbell and Olson, 1991; Maguire *et al.*, 1991). One approach can be to address the problems in stages. In the first stage, population and environment may be evaluated on continental to global scales. The location of the environmental hotspots worldwide may be determined. This first stage also provides the context for more detailed study of society-environment interactions.

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Conceptually, interactions between population and environment are rather poorly understood at the global scale. According to Malthusian view, population pressure causes environmental degradation and threatens resources but this may be an oversimplification at the global level (see Campbell and Olson, 1991).

In the second stage, the population-land issue may be examined critically and problem areas identified within a country, using population pressure and other indicators, and indicators of environmental degradation.

The third stage can focus on local, field-level patterns and processes, using household surveys, large-scale aerial photography, statistics, and qualitative methods.

Figure 3.5 summarizes some of the causes of pressure on land.

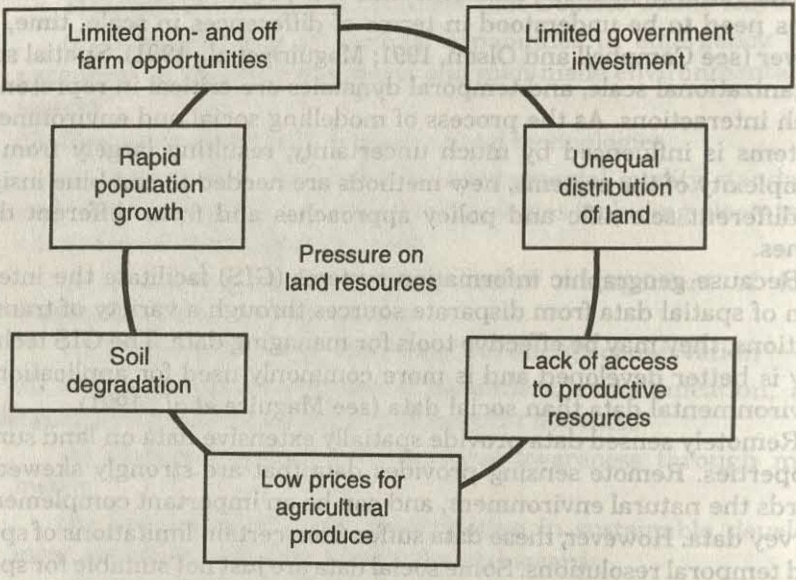
Limited non- and off farm opportunities
Limited government investment
Rapid population growth
Unequal distribution of land
Pressure on land resources
Soil degradation
Lack of access to productive resources
Low prices for agricultural produce

Fig. 3.5 Some causes of pressure on land resources.

It is essential that fundamental driving forces of environmental change are properly identified as a basis for effective remedial policy. All three (local, regional, global) of the identified scales of analysis need to be addressed for a coherent data integration. Further, conceptual development should be based on a stronger interaction between the scholars interested in landscape ecology and those interested in political ecology.

CONSERVATION OF TROPICAL ECOSYSTEMS

One of the strongest reasons to conserve tropical ecosystems is the likelihood of finding new pharmaceuticals from tropical forests. The importance of the rosy periwinkle (*Catharanthus roseus*) in treating childhood leukaemia and Hodgkin's disease best exemplifies the need for conserving rain forests. Another justification for conservation is the use of forests as pharmaceutical 'factories' to produce local medicines used in primary health care. It is quite conceivable that new therapies for diseases such as AIDS and cancer may be existing in tropical forests. Unfortunately, though there are numerous valuable chemicals to be derived from forests, these remain masked among thousands of species and billions of hectares, and to find them is like searching for a needle in a haystack. Local people traditionally have not benefited from discoveries of new medicines, and have no incentive to manage forests to encourage discovery.

An immediate incentive for conservation may be the role of tropical forests in providing traditional medicines and rural health care where local plants comprise most of the ethnopharmacopoeia. Some 2.5–3.5 billion people worldwide use traditional medicines as part of their primary health care programme.

Use of at least some areas of rain forest as extractive reserves for medicinal plants is economically justified. A periodic harvest of medicinal plant materials is a sustainable method of utilizing the forest.

ECONOMIC GLOBALIZATION

The relationship between the environment and the modern global economy is quite different than its interface with more local or regional economies. Economics is ill-equipped to deal with the effects of globalization of the economy on environmental management. Growing dependence on modern technologies shifts environmental and social problems from the local and immediate to the distant future. Increasing urbanization distances people from the soil and water on which they depend. Increasing globalization distances people from the socio-environmental effects of their consumption. Although distancing makes it harder for people to be environmentally aware and to design, implement, and enforce environmental management strategies, at the same time global communication is also becoming instantaneous and affordable for the rich people.

The globalization of regional economies has been erroneously rationalized by the logic of trade. Free trade can be a good policy only if it is also assured that there are no costs and benefits external to the trading parties. The difference between an individual trader's interest and community interest is intimately connected to the systemic character of environmental systems. It is not possible to divide up nature and assign parts of it to individuals, and therefore the markets fail to reflect its value.

Existing economic models are not good enough to preserve biodiversity because each model incorporates assumptions about the interrelationships of science, technology, and materialism that have driven the development and the accelerated biological transformation of the past century. A new and more comprehensive model is needed for finding common ground on these larger issues.

Development may be considered as a process of coevolution among knowledge, values, organization, technology, and environment (Fig. 3.6). In the coevolutionary perspective, environmental subsystems are treated symmetrically with the subsystems of values, knowledge, social organization, and technology. New technologies exert new selective pressures on species while newly-evolved characteristics of species, in turn, select for different technologies. Transformations in the biosphere select for novel ways of understanding the biosphere. For example, the use of pesticides selects for resistance and secondary pest resurgence which, in turn, select both for new pesticides and for more systematic ways of designing pest control.

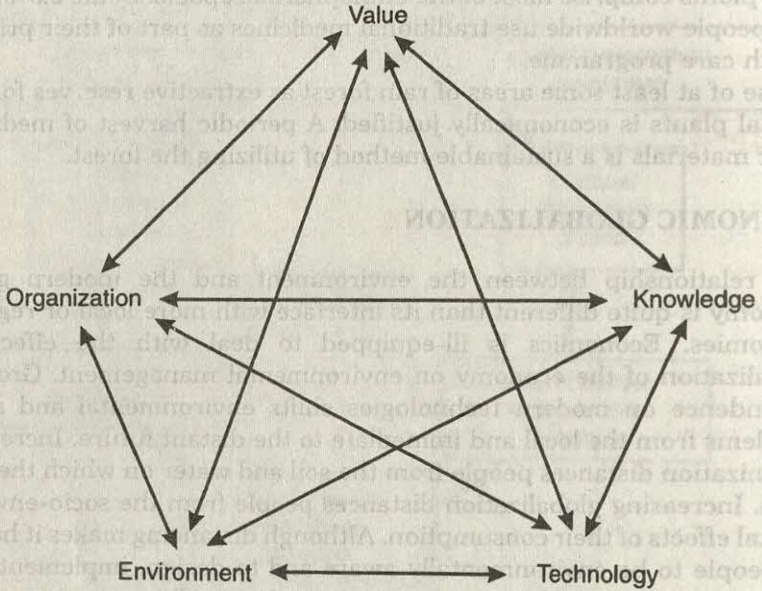

Fig. 3.6 Coevolutionary model of development showing interrelationships involved.

In the short run, people can be thought of as interacting with the environment in response to market signals or their absence. The coevolutionary model incorporates both short-term and long-term evolutionary feedbacks.

ENVIRONMENTAL SECURITY

Research on environmental security has generally focused on issues of resource depletion and violent conflict. The root cause of many violent conflicts in history being competition for territory and resources, such conflicts are likely to intensify as resources become more and more scarce.

A new dimension added in this area is the realization that environmental stress caused by global environmental change can be a cause of conflict and insecurity. In the context of environmental security, much of the research focus has been on assessing the relationship between environmental degradation and conflict. But we are now moving towards a 'third wave' in research on environmental security; this may be characterized by better methodological approaches, more empirically-based and participatory research, and better collaboration among scholars from interdisciplinary perspectives from both the North and the South.

There is need to focus on two related sets of activities. The first is to facilitate links among researchers, policy makers, and stakeholders working on environmental security. The second is to foster effective international cooperation on specific research activities within the broader environmental security framework. Two examples of specific topics may be environmental degradation, population displacement, and security; and environmental change, adaptation, and security.

GLOBAL ENVIRONMENTAL PROTECTION

Increasing economic activities of expanding populations interfere with the earth's natural systems and pose many critical environmental threats: degradation of soils, water, and marine resources; air and water pollution; global warming that could disrupt weather patterns and raise sea levels; loss of habitats, species, and genetic resources that is damaging ecosystems and the services they provide; and stratospheric ozone depletion.

Scientists had warned about some of these problems long before the general public took note. For instance, the first article on an anthropogenic greenhouse effect was published by the Swedish scientist Svante Arrhenius in 1896. The first serious effort to place environmental problems on the international agenda occurred at the Stockholm United Nations Conference on Human Environment in June 1972, the main theme being the domestic environment. Fifteen years later, in 1987, the World Commission on Environment and Development (the Brundtland Commission) coined the term "sustainable development" and called for measures that sustained human progress not just in a few places for a few years, but for an entire planet and into the distant future.

In the late 1970s and 1980s, global environmental concerns started assuming serious importance, and scientists started linking the decrease in stratospheric ozone levels to the emission of chlorofluorocarbons (CFCs). In 1990, the Intergovernmental Panel on Climate Change (IPCC), in its first assessment report, warned about an increase in global mean temperature of several degrees Celsius by the end of the twenty-first century unless drastic measures were taken. There was increased concern about the continuous decline in global biological diversity.

These danger signals and the need for sustainable development catalyzed several international activities dealing with the global environment.

In 1987, the Montreal Protocol was signed, calling for the phasing out of substances that deplete the ozone layer. Conventions on climate change and biodiversity were signed at the Earth Summit in Rio de Janeiro in 1992. On the whole, the Earth Summit accords show a clear recognition by policy makers that degradation of the environment and depletion of earth's valuable resources not only impede economic development but also threaten human survival. The Convention on Biological Diversity (CBD) constitutes one of several conventions and international agreements that could also include forests and hazardous waste.

Although many actions may have national economic and environmental benefits from a developing country's perspective, the global environment can carry little weight as compared to the more pressing needs of these countries to remove poverty.

To aid the developing countries in tackling environmental issues, a Global Environment Facility (GEF) has been created with grants from many advanced countries. Table 3.2 lists some programmes funded through this facility.

Table 3.2 Initial GEF operational programmes

Focal area	Programme
Biodiversity	Arid and semiarid ecosystems Coastal, marine, and freshwater ecosystems and wetlands Forests Mountain ecosystems
Climate change	Removing barriers to energy conservation and energy efficiency Promoting adoption of renewable energy by removing barriers and reducing implementation costs Reducing long-term costs of low greenhouse gas-emitting energy technologies
International waters	Water body-based programme Contaminant-based programme

The real need is pursuing sustainable economic development while protecting the global environment but this is a complex task requiring sustained effort, sound knowledge, and good international cooperation.

The following is a list of some priority areas of environmental concern that are being funded by the GEF through such agencies as UNEP (United Nations Environment Programme) and UNDP (United Nations Development Programme):

(1) *Economics of greenhouse gas mitigation.* Economic analysis of

climate change mitigation strategies which may help establish a common methodological framework for calculating the cost of climate change mitigation activities.

(2) *Alternatives to slash and burn.* To fund sustainable alternatives to slash-and-burn agriculture by standardizing methodologies, assessing biophysical and socio-economic characteristics, and analyzing the impact of slash and burn.

(3) *Global biodiversity assessment.* State-of-the-science review of our knowledge about the main issues of biodiversity.

(4) *Monitoring of greenhouse gases including ozone.* Establishment of key stations where data needed for scientific assessment are collected and analyzed. Activities include surveying potential sites, arranging means of local collaboration, facilitating construction, and procuring equipment.

(5) *Methane emissions from rice fields.* To quantify the impact of rice-growing ecosystems on methane emissions to improve the knowledge of processes that control CH_4 fluxes from flooded rice.

INTEGRATED ENVIRONMENTAL MANAGEMENT

Some general guidelines approved by the United Nations Environment Programme (see ECE/UNEP, 1994) for integrated environmental management especially in developing countries are as now discussed.

Strengthening Policy Development

Environmental policy, planning, and management are adversely affected by such factors as inadequate legislation, lack of political clout of environmental authorities, low public awareness, limited target groups, inadequate information, and lack of financial resources.

Generally, the national level formulates the policies, objectives, and programmes and follows them up. It should also be responsible for legislative proposals, development of environmental permits, impact assessment procedures and methodologies, integration between environmental and sectoral policies, coordination, promotion of research and education, and international cooperation.

Dependence and subordination of environmental functions to regional development structures should be avoided and environmental impact assessments should be carried out independently in an unbiased manner.

There should be effective environmental inspection units and coordination among various concerned ministries.

Environmental policies should be considered on an equal footing with other policies and environmental legislation should be consistent, comprehensive, integrated, coherent, and strict. Environmental considerations should be included in sectoral policies, plans, and programmes at all levels of government with good monitoring and evaluation. Environmental impact assessment should be mandatory, public authorities should periodically report on the status of the environment, private corporations and economists should give regular information on their activities. The public should be given the right to have environmental information.

National legislation may also be adapted to the requirements of international agreements and treaties.

Environmental standards to be enacted must be feasible and enforceable, and should be coordinated with realistic compliance schedules which should be aimed at achieving sustainable growth. Permits should be issued for specific periods of time, subject to review, monitoring, termination, reporting, and compliance schedules.

Effective responsibility and liability systems must be developed and enforced. The principles to be applied include preventive action, polluter pays, public rights to request termination, and restriction of polluting activities, and also compensation for pollution damages. Strict liability and financial security schemes to cover environmental damages are endorsed. There should be effective sanctions, including the suspension and revocation of permits and the discontinuation of activities that violate environmental requirements and seriously threaten human health and the environment.

Environmental policy should be based on the following principles: precautionary, polluter pays, sustainability, prevention of pollution at the source, concerted actions, and shared responsibility.

Environmental protection should rest on an integrated, cross-media approach, including water, soil, and air, in such a way that the protection of one medium does not result in damage to another. Objectives might be regional. Transboundary and global problems deserve to be given due attention and commitments.

There is a need to promote public participation in environmental decision-making, based on increased public awareness and access to environmental information. The information from companies to the public may include policies, objectives, targets, environmental activities, performance, and status of environmental management systems.

Reform Processes

Privatization differentiates the regulated from the regulator, allowing monitoring without a conflict of interest. Privatization needs to include both environmental objectives and traditional objectives. Environmental clauses should be a part of the model privatization contracts on par with standard clauses on investments and benefits.

Guidelines on environmental damage, responsibility, and liability should be explicit and uniform. Responsibility and liability for past environmental damage must be decided before privatization, when property rights still rest with the state.

Environmental risks associated with environmental clean-up and remedial clean-up programmes should be finalized before completing the transactions.

Rural reform should include specific provisions for the protection of groundwater and soil and surface waters, conservation of biodiversity, and protection of landscapes. Protected areas must be specifically assigned adequate management programmes (ECE/UNEP, 1994).

Environmental authorities should take advantage of the restructuring of national economies to integrate environmental requirements within economic policies, and to improve the environmental attitude and performance of economic sectors. The principles to be applied in this regard include the five R's, namely, reduction, replacement, recovery, recycling, and reuse.

Self-regulation by the private sector needs to be encouraged. There should be voluntary efforts to comply with environmental standards and to use more environmentally-sound approaches and voluntary ecoaudit schemes. Ecolabelling is another important tool.

It is very important that environmental resources are properly priced and environmental costs are internalized. Economic instruments should be linked to regulations, standards, and other means of public and administrative control. The guiding principle should be polluter pays and user pays, with appropriate allowances and compensation schemes for the poor people. Rates should be high enough (higher than the cost of actual prevention or reduction) in order to encourage environmentally-responsible behaviour. They should form part of a system including penalties, enforcement, and monitoring measures.

However, price escalation should be accompanied by income support measures for vulnerable groups. Water and water-related services should be appropriately priced. Emission trading is encouraged provided that there are suitable scales, large numbers of polluters, and adequate controls.

The possibility of ratifying or adhering to environmental conventions on air pollution; protection and use of water resources; handling of hazardous waste; environmental impact assessment; prevention; preparations for and responses to industrial accidents; climatic change; protection of the ozone layer; biodiversity; nature conservation; and protection of the marine environment should be given particular attention. The provisions of the conventions should be reflected in national legislation.

The socio-economic conditions that prevailed after the Second World War spawned the modern environmental movement. This period was one of the most socially-tumultuous eras in western history: the Cold War, Civil Rights Movement, Vietnam War, and increasing consumerism, outdoor recreationalism, and youth culture (see DeSteiger, 1997). Modern environmentalism was fuelled by youth social protest. Another event that triggered modern environmentalism was the publication of the book *Silent Spring* by Rachel Carson. Rachel Carson's views heralded the modern environmental era.

Environmentalism was born of some irreverence to the establishment, and has been influenced by economists and economic considerations including forestry.

The age of environmentalism probably peaked some time between 1965 and 1975. Certain notorious environmental disasters (e.g., Love Canal, acid rain) carried environmentalism into the 1980s when environmental writing became commonplace in magazines and newspapers.

During the past decade, the environmental policies of many national and international agencies have changed significantly with the shift of attention from top-down and authoritarian approaches in the field of conservation to community-based natural resource management. Three countries (Costa Rica, the Philippines, and Senegal) particularly have made serious efforts to promote people-centred or participatory conservation and development (see Utting and Jaubert, 1998). And yet, at least in Senegal, a significant gap still exists between government or agency rhetoric and actual practice because participation often lacks any real substance, the objectives of decentralization have been undermined by social divisions and bureaucratic resistance, and certain features of structural adjustment have thwarted conservation efforts.

GLOBALISM AND LOCALISM

Globalism and localism are not disparate but complementary concepts. Globalism reinvigorates nascent localism, which in turn legitimizes globalism. This complementarity is best illustrated by one of the world's best known corporations, McDonald's. Each McDonald's restaurant is a franchise that is locally owned, locally patronized, and locally accountable and yet the name is global, the service is virtually the same throughout the world, and the company is regarded as being global. A local act of protest over rates of pay, the animal welfare record of suppliers, the destruction of habitat to increase cattle production, or the use of hormone additives or genetically-modified substances thus assumes global significance. McDonald's cannot avoid the universal appeal of its reputation. The corporation preserves its reputation by being a good corporate neighbour. It buys locally.

One of the several prognoses for the present millennium is the resurgence of localism in the name of globalism. In Europe, some countries are already responding to the Europeanization of business and economic policy and such response may well replicate throughout the peripheral areas of Europe and elsewhere. The European Union is attempting to implement subsidiarity effectively, i.e., the allocation of governmental responsibility to the most appropriate level of action. Subsidiarity generally means retaining the authority and autonomy of national government. But in the longer term, it may mean re-empowering local communities to take their futures more into their own hands through local versions of Agenda

21 of the 1992 Rio de Janeiro Earth Summit (O'Riordon, 1998).

It appears that the resurgence of localism may emerge as the twenty-first century extension of the environmental movement that took hold in the later decades of the twentieth century. There is no single track to the future, but whichever course of action is chosen, will have to combine globalism and localism creatively and intelligently.

HUMANISM AND GLOBAL CHANGE

It is now being increasingly realized that there is need to consider not only the physical, chemical, and biological aspects of global change but also its human dimensions, that is, the ways in which human behaviour might contribute to such change as well as to the effects of environmental changes on individuals and society. Some pertinent human dimensions in this context are the potential impacts of climate change (OECD, 1993) and stratospheric ozone depletion on human health; the attitudes toward the environment in different countries; the influence of trade on the environment; the nature of governmental approaches to environmental problems; and the interactions between environmental risks and human security. The interactions between human activities and global environmental change are highly complex and need to be assessed in an integrated, intelligent manner.

Consumption as a cause of environmental degradation, human choice and climate change, and land use, and population and the environment are attracting debate, as also the relationship between globalism and localism in the transition to sustainability. New applications of systems theory and analysis are being found in analyzing some of the complex interactions and there is increasing interest in understanding the interactions between the local, regional, and global scales of analysis.

The ultimate aim of research on the interrelations amongst industrial transformation, global environmental change, and human security is to understand the human drives and mechanisms that might enable the industrial system to move toward greater sustainability and, in physical terms, to decouple industrial activities from their environmental impacts. There is need to distinguish individual industrial sectors and research fields oriented toward systems analysis, industrial ecology, and the role of consumers. It is gratifying that there is already some research activity on the evolution of environmental and sustainability interests in industry (see OECD, 1993a, c, 1995).

The study of humanity's role in global environmental change needs to involve business, non-governmental organizations, and government policy makers as well as academicians. Also, more needs to be done to ensure that this research has a tangible impact on environmental policy, especially in developing countries (Jäger, 1998).

ELECTRICITY, HEALTH, AND ENVIRONMENT

Today, the world is faced with two conflicting realities: on the one hand, we need more electricity, and on the other hand, we must pursue a path of sustainable development. In the coming years, energy demand will increase rapidly in the developing world, particularly in Asia. At the same time, the potential negative environmental and social impacts of increasing energy consumption and production are being duly recognized and appreciated. Meeting this growing demand requires investment in power plants and infrastructure, and also in the appliances and equipment which consume electricity.

If the growing electricity demand is to be satisfied in a sustainable manner, then we will have to ensure that investment decisions take into account pertinent aspects of the environment at the local, regional, and global levels.

Electricity is but one component of the energy spectrum and must enter as an option along with other forms of energy. The challenge is to use electricity in such a way that the services required for human welfare, comfort, industry, and transportation can be provided sustainably (see OECD, 1993a).

In the field of energy, there is need to encourage greater incorporation of environmental concerns into the economic decision-making process affecting energy production, transportation, and consumption.

Electricity is unique among energy forms. It is an essentially 'clean' fuel, giving rise to virtually no environmental damage at the point of consumption, but the generation of electricity often gives rise to serious environmental damage.

Electricity makes possible clean and efficient energy use in households, transport, and industry, with enormous potential benefits to human health and well-being. To provide electricity to growing populations with increasing standards of living and expanding industries, however, power must be generated in huge amounts. This means potentially serious environmental impacts such as air pollution, inundation of land for hydropower, and spread of radioactive material. Accordingly, there is need to promote environmental awareness and to incorporate environmental issues into energy planning and policies by:

(1) Encouraging environmental sustainability in governmental and private sector decisions on energy policies, programmes, and infrastructure in developing countries.

(2) Encouraging increased use of energy-efficient technologies and renewable energy technologies through market forces in developing countries.

(3) Encouraging integrated resource planning in developing countries.

(4) Defining environmental requirements in contracts for private power producers.

(5) Identifying and encouraging removal of barriers against implementation of environmentally-sound energy options.

ENVIRONMENTAL BENEFITS OF ELECTRIFICATION IN DEVELOPING COUNTRIES

The use of electricity doubtless has beneficial effects at least for the local environment. Its use in certain industrial and household tasks, instead of fuel consumption, often spells greater efficiency as well as less pollution and fewer health hazards.

While there is now cent per cent availability of electricity in the industrialized countries, much still remains to be electrified in developing countries. Within the household sector, for example, the use of biomass fuels for cooking leads to serious local and indoor air pollution. Several women and children are being exposed to dangerous levels of pollutants every day, with serious consequences for health. Indeed, respiratory illnesses directly attributable to smoke from biomass fuels constitute a major cause of serious health problems in several developing countries.

The provision of biomass fuels often damages the environment. The harvesting of wood for fuel is rarely the main cause of deforestation; clearing for new agricultural land is the most frequent culprit. Yet there can be strong local impacts, with large areas of forest being cleared for conversion to charcoal to satisfy the urban household demand for cooking fuel.

Proper ventilation and improved stoves offer possibilities for improving indoor conditions, and sustainable forestry can greatly reduce the loss of trees. Nevertheless, in many cases, electrification can be a good solution. Electrification of periurban areas in developing countries requires external assistance but gives long-term social benefits. The provision of electricity is conducive to better standards of living and also to eliminating indoor and local air pollution. Substitution of biomass fuels may also have environmental benefits, although the connection is not always a clear one of reduced deforestation.

Rural electrification, on the other hand, used to be advocated extensively in the 1970s and 1980s as a catalyst for rural development; in reality, it has not always been successful. Often, the costs of centralized grid connection are exorbitant and it is here that decentralized renewable energy technologies can have an important role.

FUEL CHAIN ANALYSIS

In fuel chain analysis, energy requirements and environmental loadings are tracked through chains of conversion processes on the basis of the efficiencies and process. Since each process may require many different inputs, the analysis can become quite complicated.

Substantial environmental impacts often occur in conjunction with stages of the energy process other than combustion. Many renewable energy technologies are highly intensive in material input, and their environmental impacts can be strong. Fossil fuel processes on the other hand exert environmental impacts at the mining or fuel extraction stage, as well as in waste disposal. A realistic comparison of alternative means of supplying energy thus requires that the whole chain of processes, and the associated environmental effects, be duly considered.

Fuel chain analysis requires the analyst to explicitly draw boundaries around systems and to allocate impacts within and between co- and byproducts of the energy system. Technology and environmental databases can prove useful in developing countries where attempts are being made to compare the environmental consequences of developing new resources and/or technologies. Local data are very often not available, and reliable sources of international data provide the best option of promoting rational decision-making.

ENVIRONMENTAL INDICATORS

Any internationally-acceptable method for assessing the environmental effects of livestock production should follow a standard pattern and be applicable to all sites and to every type of livestock production system.

The concept of environmental indicators is based on the OECD (1993, 1993a, b) view which groups the environmental indicators in a pressure-state-response (PSR) model. The model as modified for the purpose of assessing livestock production systems is shown in Fig. 3.7. It is based on the following causal relationships. Livestock production exerts a pressure on the ecosystem and so modifies the quantity and quality of the environmental parameters and of the natural resources. This modification is described in terms of state indicators. The assumption is that, sooner or later, changes in state in the ecosystem lead to a reaction in society which expresses itself in behavioural changes, legal changes, and prices, and can be displayed in the form of response indicators. Ideally, environmental indicators must satisfy certain requirements: they should be easy to record, replicable, financially justified, and should display a high degree of correlation with the situation described, namely, the environmental effect of livestock production (Hoffmann *et al.*, 1998).

AN ENVIRONMENTAL MATRIX

An integrated network can be conceived that qualitatively relates environmental actors and environmental systems within a social unit such as a town and an industrial district. The resulting matrix should bring out the flow of decisions and information between its active vector representing the environmental objectives, and its passive vector representing the environmental achievements (see Fehr, 1998). Fehr determined and compared the properties of environmental systems to the expectations generated by provisions of the environmental actors. The result was a set of

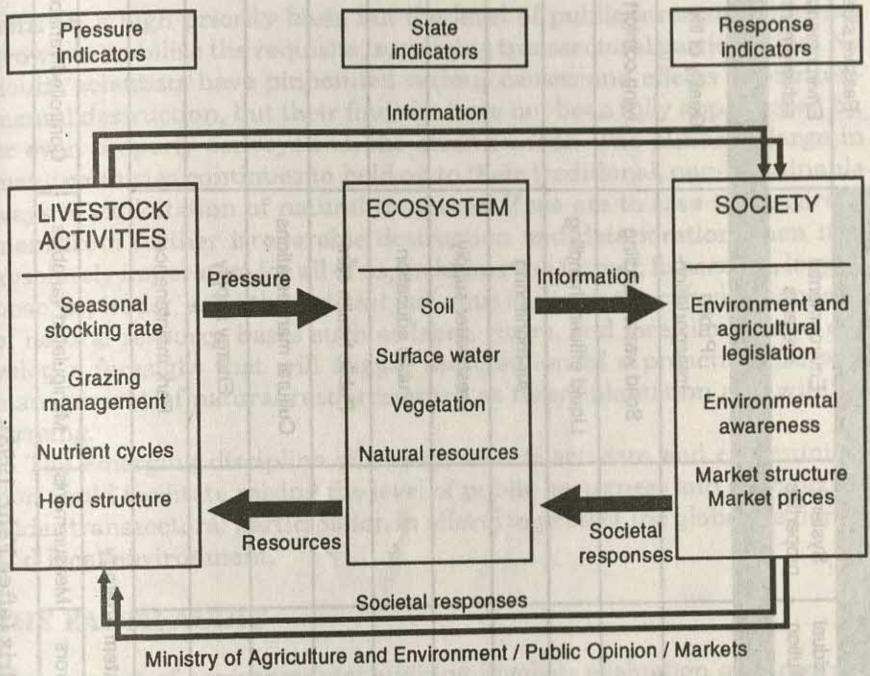

Fig. 3.7 Pressure-state-response model for livestock production (after OECD, 1993).

residuals that define the living comfort in a social unit. The network can motivate concerned parties (e.g., administrations, schools, individuals) to attempt to find the causes of the residuals. In order to eliminate them, definite responsibilities must be assigned to community members. Most if not all citizens should be involved in the flow of information, facts, and decisions, and they should be encouraged to identify themselves in the matrix.

Comfortable life is intimately associated with a high quality environment but the responsibility for this quality is quite diffuse. Global issues are addressed by intergovernmental institutions. Solutions to local issues are usually expected of municipalities. Although ultimately legislation seems to be the only means of effective interference in the quality of the environment, there are several technical and cultural factors that have a role in the construction of a good environmental matrix. The integrated environmental matrix (see Fig. 3.8) rests on a holistic approach that manages to trace the functional relationships of different individual elements and their combined influence on the quality of life (Fehr, 1998).

ENVIRONMENTAL ACTIVISM

The worsening state of the environment in many developing countries underscores the necessity to attend to many of the environmental prob-

Active side						Passive side
Environmental goals or objectives	Environmental actors	Acts of provisions	Residual pollution	System properties	Environmental systems	Environmental achievements
Satisfaction of citizens	Public administration and its ramifications				Public transportation	Quality of life
Intrinsically low values of residual pollution	Social institutions				Solid waste handling	Living comfort
	Educational institutions				Liquid effluent handling	
	Population at large				Air-monitoring	
	Medical institutions				Freshwater supply	
	Local industry				Public education	
	Local services sector				Public health care	
					Cultural manifestations	
					Energy supply	
					Park maintenance	

Control system analogy

Operating objectives	Control engineers	Set points	Errors	Measurements	Manipulated variables	Controlled variables

Fig. 3.8 Environment matrix (after Fehr, 1998):

lems on a high priority basis but the level of public awareness has not grown to mobilize the requisite, sustaining transsectoral participation. No doubt, scientists have pinpointed various causes and effects of environmental destruction, but their findings have not been fully appreciated by, or even properly conveyed to, the common man. The public at large in many countries continues to hold on to their traditional, non-sustainable ways of exploitation of natural resources. If we are to save the environment from further irreparable destruction and deterioration, then it is absolutely imperative for all of us, including the farmer, fisherman, logger, poacher, trader, and others, to set judicious limits on the carrying capacity of natural resource bases such as lakes, rivers, and forestlands, and develop a foresight that will trigger the creation of a proactive use and management of natural resources such as forest plantation and wildlife farming.

The emerging discipline of environmental activism and communication could facilitate raising the level of public awareness and galvanizing wider transsectoral participation in efforts to protect the global, regional, and local environment.

THE EARTH AUDIT

The concept of environmental auditing involves evaluation of corporate environmental performance. In the development of the *earth audit*, the auditing idea is being applied on a global scale with an eye to sustainable development. When completed, earth audit will reflect the impact of environmental damage on society and will point to the economic opportunities for reducing such damage.

Mankind has continuously polluted ecological systems, depleted mineral reserves, and degraded renewable resources. These environmental damages have not only caused great losses of natural values and beauty, but have also exerted serious social and economic impacts such as loss of productivity, material damage, human health problems, and declining economic activity.

The earth audit will aid in the transition towards sustainable development by sharpening the perceptions of how environmental degradation affects our social and economic systems. Earth audit may be described as an objective assessment of the costs accruing to human society as a result of resource scarcity and links damage, which develops nationally, regionally, and globally. Damage costs and defensive expenditures are key parameters in the operational framework.

The earth audit may help identify ways to reduce environmental degradation in a progress towards sustainable development. Such a function will depart from a benefit/cost framework in which the environmental costs are compared to efforts needed for improving the environment. Such efforts are options of public and private investments and other measures considered in environmental management programmes.

A major motive driving the development of the earth audit is that sustainable development must be promoted to a broader audience beyond those already convinced. This can involve trade-offs between environmental objectives such as safeguarding untouched nature, cleaning up aquifers, and reducing resource consumption on the one hand, and socio-economic objectives on the other, including creation of jobs and provision of housing, heating (or cooling), and electricity.

4

Food, Nutrition, and Agriculture

INTRODUCTION

The twentieth century has witnessed remarkable progress and advancement of human society, both in developed and developing countries. Some of the latter were able to achieve as much progress over the past three or four decades in grappling with the challenges of poverty, hunger, and disease as the advanced industrial countries covered in a century (IFPRI, 1995; Hazell, 1999). Several developing countries have succeeded in doubling their school enrolments, halving infant mortality and adult illiteracy, reducing malnutrition by about one-third, and extending average life expectancy at birth by 20 years (UNDP, 1998). However, a great deal still remains to be done despite these gains. Poverty continues to limit access to food, leaving millions of people undernourished in developing countries (Conway, 1998). Over the next 4–5 decades, increased population, income growth, and urbanization may possibly lead to a doubling of food needs in developing countries. One promising approach to meeting this crisis is by increasing future food security through biotechnology and promoting sustainable agriculture not through multinational corporations but through *smallholder* farmers (see Leisinger, 1995; Rifkin, 1998; Kendall *et al.*, 1999; Serageldin, 1999).

Around 1 billion people in the world do not have enough to eat or are not yet free from the fear of hunger (i.e., those who are not food-secure). Two decades ago, food security used to be viewed mainly in terms of food supply at the global and national levels, but since then, major shifts have occurred in the concept of food security—there is now more emphasis on access to food rather than purely on production (see Vijayalakshmi, 1993).

A food-based approach may be the only solution to nutritional problems in developing countries. Attention needs to be given to the causes of malnutrition, basic nutrition, deficiency disorders, foods, and nutrition policies and programmes (see Latham, 1997).

In many parts of India, people suffer from vitamin, mineral or micronutrient deficiencies. Iodine deficiency disorders are common in some places in Uttar Pradesh and Bihar. One illustrative example is the average protein and energy intake of some Indian forest peoples (see Table 4.1). Table 4.2 shows some common foodstuffs consumed by these people in various states of India. Table 4.3 lists some common foods and their nutritional value.

The nutritional needs of the more vulnerable populations like the pregnant, the lactating, infants, and elderly deserve special focus.

Chronic disorders and malnutrition result from famine, starvation, and

Table 4.1 Protein and energy intake of some Indian forest peoples (after UNESCO, 1978)

State	Protein (g/day)	Energy (kcal/day)
Assam	69–85	2430–2550
Bihar	34–74	1210–2210
Gujarat	35	1210
Kerala	30–37	1830–2228
Maharashtra	36–41	1350–1540
Tamil Nadu	27–50	1310–1870
Andaman and Nicobar Islands	130–136	2620–3050
Arunachal Pradesh	53	2530

Table 4.2 Common foodstuffs consumed by Indian forest peoples (after UNESCO, 1978)

State	Main food(s)	Subsidiary foods
Assam	Rice	Animal foods, leafy vegetables, alcoholic drinks, fruit
Bihar	Rice, millets, root vegetables	Millets, vegetables, pulses, leafy vegetables
Gujarat	Millets	Rice, fats and oils, fruit
Kerala	Rice	Pulses, root vegetables, fruit
Maharashtra	Rice, root vegetables	Root vegetables, millets, sugar, pulses, animal foods
Arunachal Pradesh	Millets, rice, leafy vegetables	Milk, pulses, alcoholic drinks

the modern-day problem of refugees. Preventive aspects and suitable methods for food fortification need more attention (Latham, 1997).

Molecular biology is being used to aid crop improvement. Genetic engineering techniques had to be adapted to fit within an effective and efficient breeding programme. In addition, the technology had to be incorporated into plant breeding programmes that could be carried out in national plant breeding programmes. Non-radioactive methodology involving chemiluminescence may be used for developing markers and also a series of computer software systems have been developed to handle the voluminous data collected. Molecular biology may not provide improved crop varieties directly but rather works best in conjunction with regular plant breeding programmes.

Table 4.3 Some selected common foods and their nutritional value (after UNESCO, 1978)

Group/Common name	Botanical name	General nutritional properties of the group
Cereals and grains		
Barley (bulrush millet)	*Hordeum vulgare*	Most supply approximately 350 kcal and 11–12 g protein/ 100 g dry weight Barley and jowar have most protein, rice and some millets least Also supply thiamine, riboflavine, niacin (maize is low in niacin) Degree of milling affects vitamin content: polished rice has one-quarter the thiamine of brown rice Excellent staple foods
Bajra	*Pennisetum americanum* (= *P. typhoideum*)	
Finger millet (ragee)	*Eleusine coracana*	
Glutinous rice	*Oryza glutinosa*	
Jowar	*Sorghum* spp.	
Maize	*Zea mays*	
Rice	*Oryza sativa*	
Wheat	*Triticum vulgare*	
Stems, roots, tubers, starchy fruits		
Banana, plantain	*Musa* spp.	Energy content similar to cereals on dry weight basis Protein content of potatoes and yams just adequate for child growth; cassava and sago low Also supply ascorbic acid Yellow yams, sweet potatoes, bananas supply vitamin A Low in B vitamins and minerals Tendency for children to be underfed when weaned on to these foods unless fat- and protein-supplying supplements are used
Breadfruit	*Artocarpus communis*	
Cassava manioc	*Manihot utilissima*	
Potato	*Solanum tuberosum*	
Sago palm	*Metroxylon sago*	
Sweet potato	*Ipomoea batatas*	
Yams	*Dioscorea rotundata*, *Dioscorea cayenensis*	
Legumes and oilseeds		
Black gram	*Phaseolus mungo*	Dried legumes contain about 320 kcal and 20–30 g protein per 100 g, plus iron, B vitamins and, in green-, yellow- or red-coloured varieties, vitamin A
Broad bean	*Vicia faba*	
Chick-pea (Bengal gram)	*Cicer arietinum*	

Table 4.3 Some selected common foods and their nutritional value (after UNESCO, 1978) (cont.)

Group/Common name	Botanical name	General nutritional properties of the group
Coconut	*Cocos nucifera*	Ideal supplements to a cereal- or root-based diet Mixed legume and cereal proteins have as high a biological value as meat
Cowpea	*Vigna unguiculata*	
Green gram (mung bean)	*Phaseolus aureus*	
Groundnut	*Arachis hypogaea*	
Lentil	*Lens esculenta*	
Oil-palm	*Elaeis guineensis*	
Pea	*Pisum sativum*	
Pigeon pea	*Cajanus cajan*	
Sesame	*Sesamum indicum*	
Soybean	*Glycine max*	
Vegetables		
Cabbage	*Brassica oleracea*	Vegetables supply vitamin C, vitamin A (dark green, yellow, and red varieties), iron (dark green varieties), folic acid, and B vitamins Leafy vegetables contribute protein in small but sometimes important amounts Their composition is variable, affected much by weather and soil conditions
Carrots	*Daucus carota*	
Cucurbits	*Cucurbita* spp.	
Green leaves	spp. of *Amaranthus, Brassica, Spinacia,* etc.	
Okra	*Hibiscus esculentus*	
Onion	*Allium* spp.	
Gourds	spp. of *Lagenaria, Benincasa*	
Pepper, chilli	*Capsicum* spp.	
Sugar cane	*Saccharum officinarum*	
Tomato	*Lycopersicum esculentum*	

Table 4.3 Some selected common foods and their nutritional value (after UNESCO, 1978) (cont.)

Group/Common name	Botanical name	General nutritional properties of the group
Fruits		
Citrus (lemon, lime, orange, tangerine)	*Citrus* spp.	Contribute vitamin A (reddish-orange fleshed varieties), ascorbic acid, and variable amounts of sugar
Guava	*Psidium guajava*	
Mango	*Mangifera indica*	
Melon	spp. of *Cucumis*, *Citrullus*	
Papaya	*Carica papaya*	
Pineapple	*Ananas comosus*	
Animal		
Milk		Source of energy, protein, vitamins A and D, calcium Low in iron and B vitamins
Eggs		Protein, energy, vitamins A and D, and B vitamins (iron not well absorbed)
Meat, fish, shellfish		Sources of protein, iron (especially red meat), vitamins A and D, B vitamins, and calcium Energy content varies with fat content Little carbohydrate or vitamin C

FOOD SECURITY

Food security may be defined as nutritionally-adequate diet available to all, now and in the future. Serious efforts are afoot at several places at preserving important plant genetic resources. The CGIAR Centres presently have collected approximately 600,000 genotypes and are the main suppliers of genetic food plant material to the developing world. No less than 50,000 wheat genotypes, 10,000 maize, 4000 potato and 80,000 rice genotypes are in the collection. Despite this, there is still a race against time—efforts to preserve important crop species must accelerate to ensure future food security. The collection of food, forage, and forest species must have a wide range and be rich in genetic diversity to be able to play a catalytic role in future food concerns. Of rising concern to the Centres is the development of intellectual property laws which contravene their long-standing policy of making genetic material available to all countries.

Biotechnology can help ensure future food security if it benefits farming activities of small and marginal farmers in developing countries. Sadly, however, much current research on agricultural biotechnology is embroiled in complex issues relating to ethics, safety, and intellectual property rights—issues not likely to benefit smallholder farmers in developing countries. Protection of intellectual property rights channelizes private sector investment in agrobiotechnology, but in developing countries the needs of most farmers and environmental conservation are unlikely to attract private funds (Serageldin, 1999).

The problem of food security cannot be tackled in isolation. It is an integral component of other development issues. The world food insecurity has resulted from undemocratic and inequitable distribution of, and access to, resources such as land, credit, information, and incentives, rather than from global food production (FAO, 1995). Food processing has a key role in ensuring food security by making safe and nutritious food available to the consumer and also as a source of livelihoods providing consumers with money to access food.

It is well-known that not all the food that is harvested reaches the consumer. Some part is lost during storage and due to insufficient or defective processing. Reducing such post-harvest losses is an important step towards increasing food availability for achieving greater food security. Even when abundant food is available, very often the goal of universal food security cannot be achieved in view of the absence of well functioning marketing, processing, and distribution systems (Dietz, 1995; FAO, 1995a, b).

A large number of food-insecure people lack access to land to enable them to produce enough food for their own needs, so they have to buy some of it. Food security for them depends on an increase in their income and purchasing power. Strengthening the food processing sector can increase access to food. For many villagers and poor people in developing countries, food processing is already an important source of income and employment. Further strengthening of this sector can go a long way in achieving food security and alleviating poverty. This is particularly important because agriculture cannot absorb the growing labour force in many countries.

Unfortunately, the food processing sector has been greatly neglected. The emphasis is usually on the resources needed for meeting growing consumer demand for food and on increasing agricultural production and productivity. Much less attention is given to the chain through which food reaches the consumer. The efforts to increase food production need to be complemented by earnest endeavours to prevent wastage of food in all forms, and the hitherto neglected issues relating to food marketing, processing, and distribution need careful planning.

Although considerable progress has occurred in improving global food security (per person availability of food for direct human consumption), the progress has been very uneven, and many developing countries have failed to register significant progress. Indeed, according to Alexandratos (1999), in some countries, the food security situation today is worse than two decades ago, even though the world already produces sufficient food (FAO, 1995a, b; Brown, 1998). The undernourished and poor people lack the purchasing power to buy food. Economic development failures account for the persistence of poverty and food insecurity. In the majority of countries with severe food security problems, the greatest part of the poor and food-insecure population depend greatly on local agriculture for a living. In such cases, development failures really mean failures of agricultural development. Development of agriculture is seen as the first crucial step toward broader development, reduction of poverty, and food insecurity, and eventually freedom from excessive economic dependence on poor agricultural resources (Ingco *et al.*, 1996).

Projections indicate that progress would continue, but at a rate and pattern that would not reduce undernutrition significantly in the medium-term future. As in the past, world agricultural production is likely to keep up with, and may even exceed, the growth of the effective demand for food. The crucial problem will be the persistence of poverty which would preclude many of the undernourished people to attain levels of consumption compatible with freedom from undernutrition (Alexandratos, 1999).

Biotechnology is emerging as a front-line technology for facing the twin challenge of food and nutritional security problems in developing countries such as India. The major impact of biotechnology so far has been on pharmaceutical and agricultural sectors, and in the coming years its impact is also expected to be felt on food and nutritional security and on environmental preservation (see Anonymous, 1999a).

Between 1996 and 1998, five industrial countries and three developing countries contributed to more than 15-fold increase in the global area planted to transgenic crops. Sale of transgenic crops was about $75 million in 1998 and is projected to exceed $20 billion within the next decade.

Some fears have been expressed recently that market dominance by giant transnational enterprises that basically control production and sales of commercial products for agribusiness, food and pharmacy, combined with monopoly patents, can result in unprecedented corporate control over the biological basis for commercial food, farming, and health (see RAFI, 1999).

Several transnational enterprises dominate commercial sale of pesticides, seeds, pharmaceuticals, food, and animal veterinary products. As traditional boundaries between the pharmaceutical, biotechnology, agribusiness, food, chemical, cosmetic, and energy sectors disappear, these giant companies will use complementary technologies such as high throughput screening, combinatorial chemistry, transgenics, and genomics to increase their profitability.

According to RAFI (1999), a radical transformation of the global economy is now taking place. Many of the world's largest chemical corporations are shifting out of commodity petrochemicals into biology, changing from industrial chemicals to agribusiness, pharmaceuticals, and food.

The total retail value of global food sales is estimated at $2000 billion, over six times larger than pharmaceutical sales. Put another way, the 1997 revenues of the world's largest food and beverage corporation (Nestle, $45.3 billion) surpassed both the entire commercial seed industry ($23 billion) and the entire agrochemical industry ($31 billion). As genetic engineering and related technologies are increasingly used to alter the function and performance of plants, animals, and common ingredients, the food and beverage industry is likely to enter into strategic alliances, mergers, and acquisitions with seed, biotech, agrochemical, and pharmaceutical firms.

With the development of so-called functional foods and nutraceuticals, the borders between food and medicine have blurred. Companies such as DuPont, Kellogg, Astra/Zeneca, and others have plans to genetically engineer foods and supposedly enhance human health, and the sales of these foods are expected to rise greatly in the coming years.

FOOD PROCESSING

Food processing begins at the moment of slaughter or harvest and ends with food consumption: this process is termed the food chain. In most cases, food is prepared solely for family consumption. However, preparation of the daily food can become an income-generating activity. With suitable training and business awareness, food processing can be a most successful small-scale business. It is one of several activities that gives flexibility and diversity in supporting survival and so can have a strong impact on food security.

Food security can be had by acquiring the ability and resources to produce one's own food, i.e., if land is available for domestic cultivation. Unfortunately, the world's poorest people have no access to land. For them, the only means of obtaining food is to have cash or other goods available for barter.

The provision of employment and increased potential for income generation is an indirect but practical way of achieving food security. Food processing at the small scale or village level undoubtedly has great potential for increasing the income and access to food for resource-poor people. It is highly flexible, requires very little capital investment, and can be carried out in the home.

Food is processed for a number of reasons, such as to preserve it for the off-season, to remove anti-nutritional components, to improve its taste and palatability, and for income generation.

Of course, some food processing technologies (e.g., canning, starch extraction, and the solvent extraction of oil) are not suitable for adoption at the small scale because they require a heavy investment in machinery and equipment, making it impossible for the small-scale producer to compete. Some technologies which are suitable include drying, pickling, smoking, fermenting, salting, and preserving with sugar.

ENVIRONMENTAL DEGRADATION AND FOOD PRODUCTION

Döös (1993) attempted to estimate the extent to which global food production is affected by the ongoing environmental degradation through processes such as soil erosion, salinization, chemical contamination, ultraviolet radiation, and biotic stress. He also discussed available opportunities to improve food production efficiency by, for example, increased use of fertilizers, irrigation, and biotechnology, as well as improved management. Expected losses and gains of agricultural land in competition with urbanization, industrial development, and forests were duly taken into account. His calculations indicate that during the next four decades, the annual net gain in food production will be significantly lower than the rate of world population growth. He also attempted to identify possible scenarios for large-scale migrations, caused mainly by rapid population growth in combination with insufficient local food production and poverty.

Figure 4.1 shows the principal factors having a positive or negative influence on the future capacity of the global food-support system under comparatively favourable circumstances. He therefore deliberately underestimated the expected losses caused by various stresses on the system, and overestimated the possible gains which can be achieved.

Table 4.4 shows various parts of the world that are severely affected by human-induced land degradation. Agricultural production is variously affected by human-induced degradation of the environment (Fig. 4.2).

LAND DEGRADATION AND CROPS DAMAGE

Human-induced land degradation is quite severe in the developing world, and is increasing alarmingly. It is often caused by inappropriate land use,

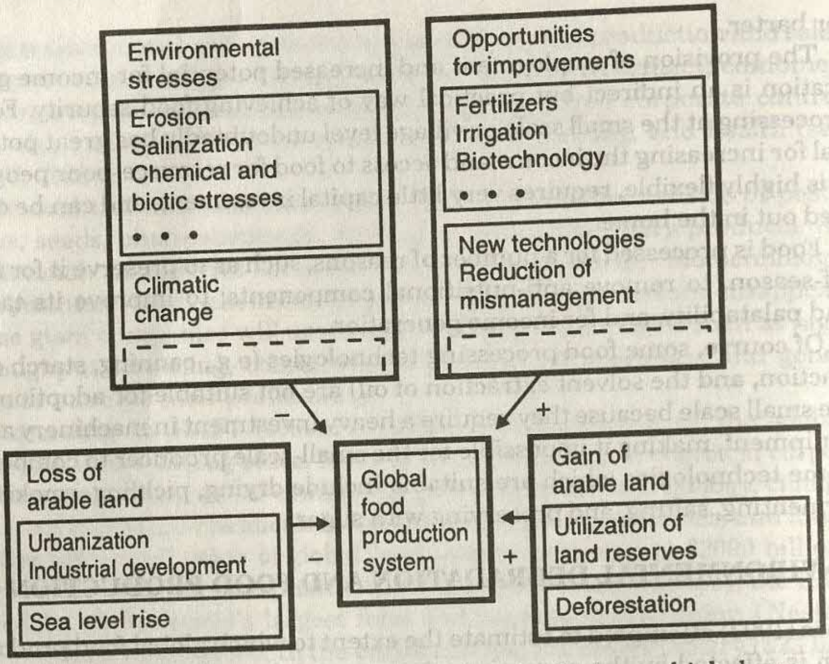

Fig. 4.1 Schematic illustration of main factors which have positive or negative influence on the capacity of global food production system (after Döös, 1993).

Table 4.4 Different regions affected more or less severely by human-induced land degradation (million hectares) (after Döös, 1993)

Type	Africa	Asia	South and Central America	Total
Water erosion	170	315	77	562
Wind erosion	98	90	16	204
Nutrient loss	25	10	43	78
Salinization	10	26		36

e.g., cultivation of steep slopes, overgrazing, and extension of cultivation into marginal areas. These driving forces of degradation are enhanced by the rapid increase in world population.

The rate of soil erosion caused by water and wind exceeds by far its renewal rate (= 0.5 cm in a century). The annual loss of soil is about 0.7% which implies that by 2025 the loss will be somewhat more than 20% of the total reservoir.

Salinization is mainly confined to irrigated areas, and its contribution to degradation of agricultural land is considerably less than soil erosion. In

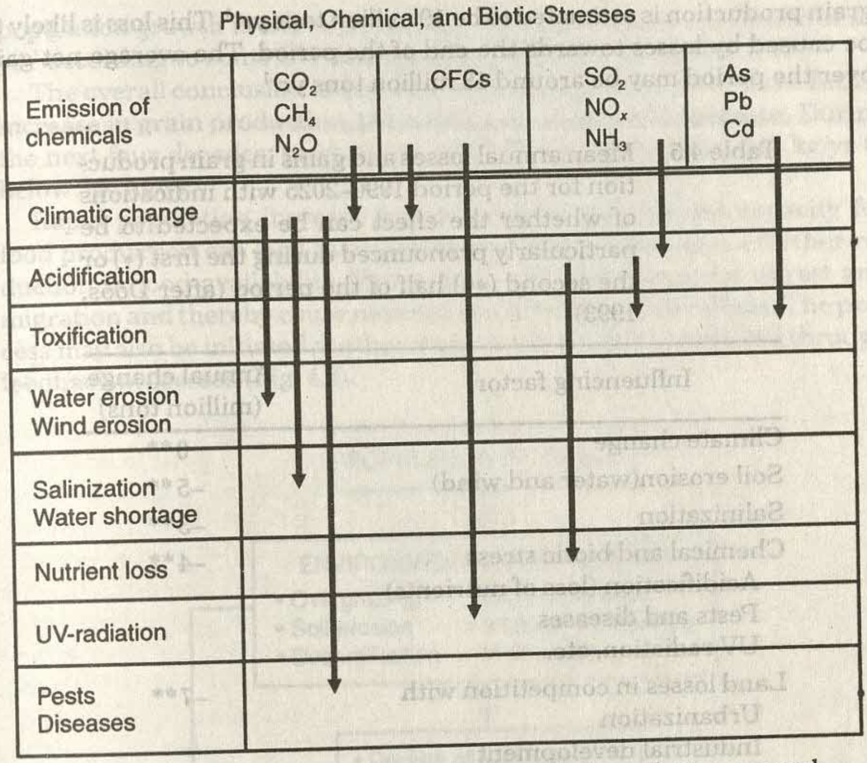

Fig. 4.2 Various types of environmental degradation caused by anthropogenic emissions of chemicals, which either directly or indirectly have impact on agriculture (CFCs, chlorofluorocarbons).

future, however, with the expected rise of the sea level and in view of the fact that some of the arable land is along low-lying coastal areas, salinization may become an increasingly important problem, particularly in Bangladesh, Egypt, and Vietnam.

Different estimates are available of present degradation and loss of agricultural land use to salinization. WCED (1987) claimed that millions of hectares of productive land are being abandoned annually, while FAO (1991) claimed that the area lost is only about 2 million hectares yr^{-1}, i.e., about 1 million hectares yr^{-1} for grain production. Using this lower value by FAO, but a somewhat higher value for the grain yield due to the higher production and often double cropping of irrigated land, the loss of grain production would be about 3 million tons yr^{-1} (Döös, 1993).

Table 4.5 gives some rough estimates of the expected gains and losses in the world grain production during the period 1990–2025. Over this period, the mean value of the expected increase of grain production is estimated to be 37 million tons yr^{-1}. This overall annual gain is not likely to change during the next few decades (see Döös, 1993). The average loss of grain production is estimated to be 19 million tons yr^{-1}. This loss is likely to be caused by losses towards the end of the period. The average net gain over the period may be around 18 million tons yr^{-1}.

Table 4.5 Mean annual losses and gains in grain production for the period 1990–2025 with indications of whether the effect can be expected to be particularly pronounced during the first (*) or the second (**) half of the period (after Döös, 1993)

Influencing factor	Annual change (million tons)
Climate change	0**
Soil erosion(water and wind)	–5**
Salinization	–3**
Chemical and biotic stress Acidification (loss of nutrients) Pests and diseases UV-radiation, etc.	–4**
Land losses in competition with Urbanization Industrial development Communication network	–7**
Sum of negative impacts	–19**
Land gains in competition with Forests Utilization of reserves	+5*
Fertilizers	+21
Irrigation	+3*
Biotechnology	+3**
Management improvements and new technologies	+5
Sum of positive impacts	+37
Net gain	+18

According to Döös (1993), unless steps are taken to reduce environmental degradation and utilize existing opportunities to increase grain production, the present net gain of about 1–2% yr^{-1} is likely to decrease to about 0.5% yr^{-1} within the next few decades.

A comparison of the estimated annual rate of change in world grain production with the rate of change in world population shows a widening gap between the expected demand and production of grain. At present, population growth is 1.72% yr^{-1} and by 2025 it is expected to be about 1% yr^{-1} according to some UN demographic estimates (see Döös, 1993).

The overall conclusion is that even with an optimistic view of the future increase in grain production, production per capita will decrease. During the next four decades, production may fall from the present 340 kg/yr to below 300 kg/yr.

Rapid population increase in combination with limited capacity for food production can lead to environmental degradation and a further reduction in food availability. This in turn can generate social unrest and migration and thereby cause national and international conflicts. The process may also be initiated at other stages and be further amplified through feedback processes (Fig. 4.3).

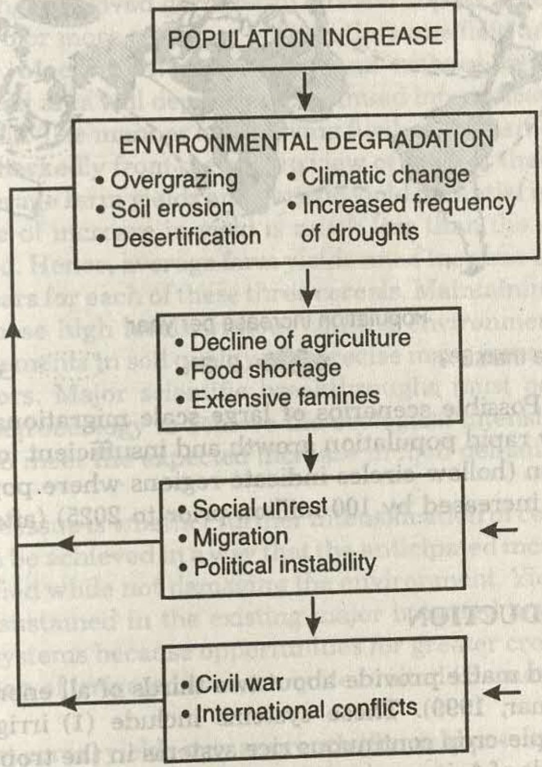

Fig. 4.3 Possible cause-effect chain linking population increase, environmental degradation, decline of agriculture, migration, and political instability, which can lead to armed conflicts; also indicated are possible positive feedback processes which may reinforce and accelerate this process (after Döös, 1993).

Returning now to the question of the risk of occurrence of large-scale migrations due to food shortages within the next few decades, a definite and conclusive answer can clearly not be given. However, taking into account the very pessimistic prospects for increasing food production at the same rate as world population growth, this being particularly pronounced in certain large-scale (subcontinental) regions, we get a very definite indication that migrations are likely to occur.

Figure 4.4 illustrates possible scenarios of large-scale migrations caused by population growth and insufficient food production.

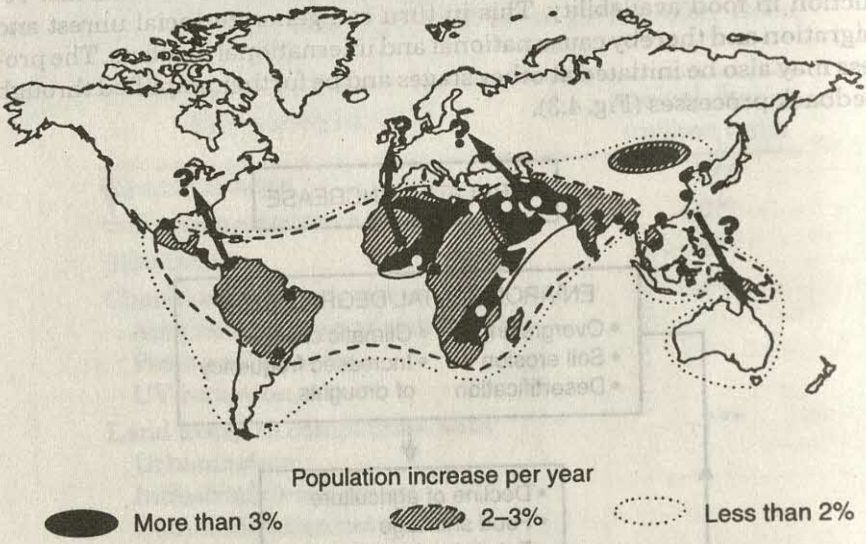

Fig. 4.4 Possible scenarios of large-scale migrations caused mainly by rapid population growth and insufficient local food production (hollow circles indicate regions where population will have increased by 100 million prior to 2025) (after Döös, 1993).

CEREAL PRODUCTION

Wheat, rice, and maize provide about two-thirds of all energy in human diets (see Kumar, 1999). These systems include (1) irrigated annual double- and triple-crop continuous rice systems in the tropical and subtropical lowlands of Asia, accounting for about 25% of global rice production; (2) irrigated annual rice-wheat double-crop system (the primary cereal production system in northern India, Pakistan, Nepal, and southern China); (3) temperate maize-based, rain-fed cropping systems of the North American plains, which contribute over 40% of global maize supply; and (4) the favourable rain-fed wheat systems of North-West and Central Europe, which account for more than 20% of global wheat supply. Yield per unit time and land has increased markedly during the past three decades (see Table 4.6) in these systems as a result of intensified crop man-

Table 4.6 Worldwide harvested area and yields of three major cereals in 1967 and 1997 and projected growth rate in cereal demand from 1993 to 2020 (after Rosegrant *et al.*, 1998)

Crop	Harvest area ($\times 10^6$ ha)		Annual growth rate (%)		
			1967–97		Grain demand
	1967	1997	Yield	Production	1993–2020
Wheat	219	229	2.3	2.5	1.22
Rice	128	150	1.9	2.5	1.19
Maize	112	142	1.8	2.6	1.49

agement involving improved germplasm, greater inputs of fertilizer, and production of two or more crops per year on the same field and irrigation (Cassman, 1999). Meeting future food demand without significantly increasing cultivated area will depend on continued intensification of these same four systems. The manner of achieving further intensification, however, will differ markedly from the past in view of the fact that exploitable gap between average farm yields and genetic yield potential is narrowing. The current rate of increase in yield is much less than the expected increase in demand. Hence, average farm yields must increase substantially in the coming years for each of these three cereals. Maintaining consistent production at these high levels without causing environmental damage requires improvements in soil quality and precise management of various production factors. Major scientific breakthroughs must occur in ecophysiology and agroecology to achieve the ecological intensification that will be needed to meet the expected increase in food demand (Cassman, 1999).

One debatable issue is whether further intensification of cereal production systems can be achieved in a way that the anticipated increase in food demand is satisfied while not damaging the environment. Yield increases will have to be sustained in the existing major irrigated and favourable rain-fed cereal systems because opportunities for greater cropping intensity and expansion of irrigated area are quite limited (Barnett *et al.*, 1995; Cassman, 1999).

It appears that cereal yields may approach the yield potential ceiling in many of the world's most productive cropping systems within the next three decades. According to Cassman (1999), ecological intensification of these high production cropping systems is crucial to achieving food security under this scenario.

GENETICALLY-MODIFIED CORN

Corn is popularly termed industry's golden crop. After rice, corn is perhaps South-East Asia's most important crop and is the private sector's favourite crop. All commercial seed sales in the industrialized world are for hybrids, which are highly profitable, and the crop's greediness for external inputs adds to agrochemical company coffers. Genetically-modified (GM) corn is the subject of more R&D and patent applications than any other crop. A variety of GM corn products are being developed for release in South-East Asia. Corn's popularity is increasing in South-East Asia where it is being transformed from an important staple for farmers and poor families into an industrial commodity.

Governments are making serious attempts to lure multinational corporations to invest in and use South-East Asia's rich paddy lands as production lines for factory farms and as testing grounds for their GM crops. The process can potentially turn farmers as mere slaves of industry, and regional food security is being increasingly threatened. The issue being hotly debated is: Will the biotech giants succeed in turning Asia's rich and vast rice paddies into a golden sea of corn reminiscent of the American Great Plains, or can corn remain an integral part of the biodiverse farming systems of local farmers? In some countries, there has been considerable opposition from the general public to undertake any field tests of GM food plants.

Genetically-modified Bt (*Bacillus thuringiensis*) corn was cleared for field testing for the first time on Philippine soil in June 1999 by the country's National Committee on Biosafety but public opposition did not let the tests being conducted. Even many government officials now recognize that GM crops can threaten food security and agricultural sustainability in South-East Asia. They also see the potential for these crops to damage environment, destroy ecological balance, erode biodiversity, and undermine farmer's autonomy and productive capacity. Farmers feel that the shift from the chemical, conventional farming system to the diversified integrated farming may be a crucial determining factor for food self-sufficiency.

Farmers have played and are still playing a vital role in the production of a diverse range of corn varieties in the field. Almost 40% of the corn area in South-East Asia is still planted to farmers' varieties (Table 4.7). Nevertheless, a number of traditional cultivated varieties of corn have already been replaced by modern varieties in many areas in Malaysia, the Philippines, and Thailand. In Vietnam, numerous glutinous corn varieties, important for human consumption and food security, have vanished. In Indonesia, there are fears over the rapid disappearance of local varieties due to current government thrusts to promote the high-yielding varieties.

It appears that products of genetic engineering may soon reach farmer's field in Asia. The import, testing, and commercial release of transgenic crops is being perceived by some to be a grave threat to farmers, consumers, and the environment in the region. In the USA, GM crops had long been approved for planting without much opposition. But in Asia, as in Europe, opposition to these crops is growing amongst farmers and the public.

On the other hand, biotech companies are touting GM crops as the an-

Table 4.7 Corn varieties grown on the farm, 1997 (after CIMMYT, 1999; FAO, 1999)

Country	Corn area ($\times 10^3$ ha)	Farmers' varieties (% corn area)	Improved varieties (% corn area)	
			Hybrids	Open-pollinated
India	6150	55	30	15
Indonesia	3355	6	23	71
Nepal	800	65	0	45
Pakistan	882	66	8	26
Philippines	2725	77	19	14
Thailand	1300	0	60	40
Vietnam	659	0	46	54

swer to the South's prayers for food security and sustainability.

TOWARDS AGRICULTURAL SUSTAINABILITY

Following establishment of the material basis for the agricultural and industrial revolutions during the eighteenth and nineteenth centuries, unprecedented growth in population, in resource use, and in human welfare ensued. Since mid-century alone, global population has doubled, energy production has more than tripled, and economic output has increased fivefold.

The challenge ahead lies in making the transition to sustainable growth in both developed and underdeveloped countries, based on transition to a stable global population, a transition to a stable level of material consumption, and a transition to a largely urban society. Whether these transitions will be accompanied by levels of material and energy consumption in today's underdeveloped countries comparable to the levels achieved by the industrial countries is a debatable issue. Even more problematical aspect is to estimate how much land will be left to nature after meeting the demands for agricultural commodities and the demands for environmental services arising out of population and income growth in the coming few decades.

There is no doubt that there will be several surprising developments in the future.

Some attempts have been made to construct plausible scenarios of alternative development paths that could arise from the forces that will drive the world system across the twenty-first century (Hammond, 1998; NRC, 1999). Scenario construction usually involves four major steps. The current state of the system is first described and quantitatively represented to clarify the key issues that will be addressed. The driving forces that govern the system and move it forward are then identified and characterized. The third step concerns identification of the forces that can redirect beliefs, behaviours, and policies from some visions of the future towards others. Lastly, an attempt may be made to impose surprising events on the scenario trajectory (Ruttan, 1994, 1999). Figure 4.5 shows some scenarios presented by the Stockholm Environmental Institute (Raskin *et al.*, 1996).

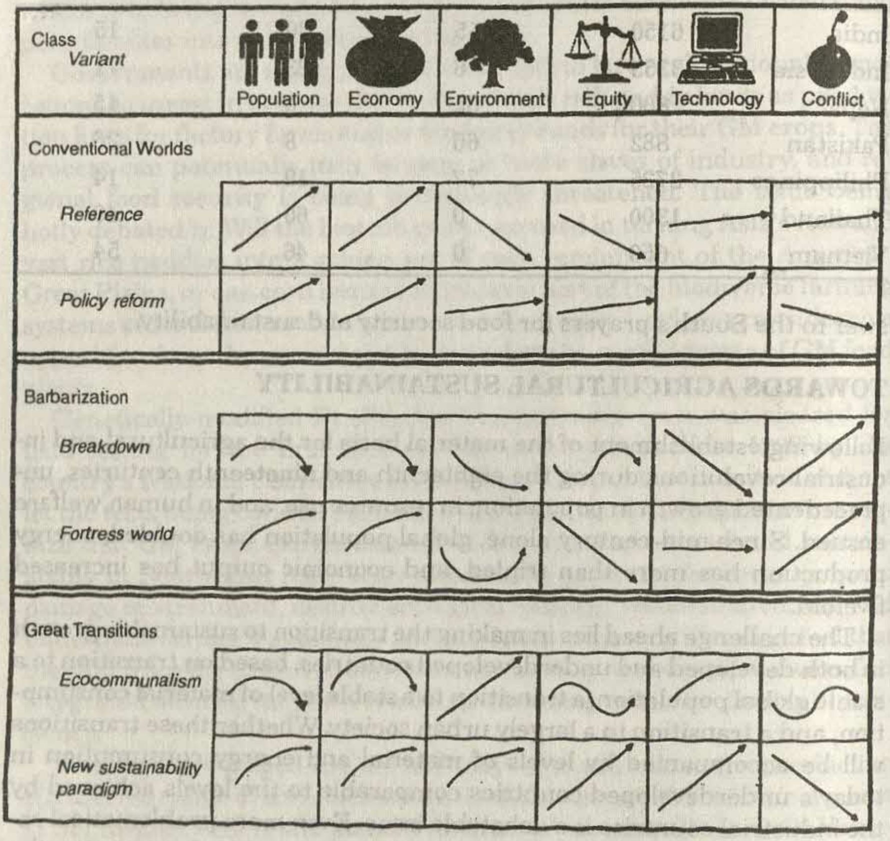

Fig. 4.5 Archetypal scenarios with possible patterns of change over time for six descriptive variables: population growth, economic scale, environmental quality, socio-economic equity, technological change, and degree of social and geopolitical conflict (after Ruttan, 1999).

The world described by the reference scenario is richer but dirtier than the world we live in at the threshold of the twenty-first century! There are also grave risks associated with the reference scenario, viz., (1) the cumulative loads on earth's geochemical cycles and ecosystems could exceed natural assimilative capacities; (2) the increased pressure on natural resources could lead to economic and social disruptions or even conflicts; and (3) the poverty in underdeveloped countries experiencing rapid population growth could generate considerable social, political, and economic stresses.

However, appropriate policy reforms/changes can result in benefits, as compared with the reference scenario, being realized in terms of improvements in environmental quality, greater equity, and a reduction in sociopolitical conflict.

The Stockholm Environmental Institute proposed two alternative scenarios, each with two variants (Fig. 4.5). In new sustainability variant (great transitions), governance and economic systems reflect a stronger sense of global community and attach a higher value to environmental amenities. The flow of energy and material through the economy is greatly reduced even with rising incomes. Incomes in the poorer nations converge more rapidly toward those in the developed countries. Growth in cultural consumption substitutes for that in material consumption. A new postindustrial culture can come only from formulating suitable technical and institutional changes to respond to challenges that will be confronted in ensuring a better quality of life for the people who will be living in the increasingly urbanized world (Ruttan, 1999).

The barbarization scenario arises out of failure to realize the institutional reforms necessary to achieve either the conventional worlds or the great transitions scenario. In the barbarization scenario, the number of people living in poverty increases while the gap between rich and poor grows—both within and among countries (see Raskin *et al.*, 1998; Ruttan, 1999). Local and regional environments become increasingly stressed, and there is intensification of conflict over access to natural resources.

SCIENTIFIC AND TECHNICAL CONSTRAINTS

Since the late 1940s, there have been unprecedented rates of growth in world population, in per capita income, and in agricultural production. World population has increased from 2.5 billion in 1950 to about 6 billion today. The production of cereal crops more than tripled in the late 1960s. Global average per capita food availability rose from <2400 calories to >2700 calories. Population growth may add 3–4 billion people to world population by 2050. The contribution of income growth to growth in food demand will depend chiefly on whether the decline in the rate of per capita income growth in the low income countries since 1980 is reversed in the next decade. Whereas income growth in rich countries imposes very little burden on per capita food consumption, the poor have to spend as much as one-half of any increase in their per capita income on food.

In the last five decades, advances in crop production came from expansion in irrigated area, from more intensive application of fertilizers and crop protection chemicals, and from the development of crop varieties that were more responsive to fertilizer and management. Advances in animal production came from breed improvements and developments in animal nutrition. Increases in grain yields stemmed from changes in plant architecture that made possible higher plant populations per hectare, and raising the ratio of grain to total dry matter. There were increases in production of animals and animal products by decreasing the proportion of feed devoted to animal maintenance and increasing the proportion used to produce usable animal products (Ruttan, 1999).

It is more difficult to predict the sources of increase in crop and animal production over the next half century than it was a half century ago. There are severe physiological constraints to increasing the grain-to-dry-matter ratio or to reducing the percentage of animal feed devoted to animal maintenance. These constraints will manifest strongly in those areas that have already achieved the highest levels of output per hectare or per animal unit—in western Europe, North America, and East Asia.

RESOURCE AND ENVIRONMENTAL CONSTRAINTS

The degradation and loss of soil resources due to erosion, the waterlogging and salinity associated with irrigation, the coevolution of pests and pathogens associated with use of chemical controls, the impact of global climate change, and the loss of biological diversity are some of the environmental effects of intensive agriculture practices on agricultural production in the coming years.

Soil erosion and degradation threaten sustainable growth in agricultural production in countries and are likely to become even more serious in the future. Harris (1990) suggested, for example, that by 2050 we may have to feed twice as many people with half as much topsoil.

It appears that the impact of human-induced soil degradation and loss is not evenly distributed across agroclimatic regions, either in developed or developing countries. The impacts on the resource base and on regional economies from soil erosion and degradation are most probably local rather than global. Soil degradation and erosion are not likely to emerge as important threats to the world food supply in the foreseeable future. But where soil erosion does threaten the resource and the economic base of an area, the gains from implementation of the technical and institutional changes necessary to reclaim degraded soil resources, or at least to prevent further degradation, can be quite substantial (Ruttan, 1999).

In many countries today, water has become a highly valuable resource, particularly in many arid and semiarid areas, where water scarcity is developing into an increasingly serious constraint of growth of agricultural production. There have been very large increases in withdrawal of water for domestic and industrial purposes and, more importantly, for irrigation; this has greatly increased its economic value. Sixteen countries, with a total population of 361 million, located primarily in the Middle East and North Africa, experienced absolute water scarcity in 1990, and by 2025, an additional 23 countries, primarily located in Africa, with a 1990 population of 345 million, plus northern China and western India, where another 360 million people live, were projected to experience either absolute or severe water scarcity. A decline in withdrawals of water for irrigation in almost all of these areas between 1990 and 2025 has also been forecast (see Ruttan, 1999).

During the last five decades, irrigated area in developing countries increased from <100 million hectares to almost 200 million hectares. About half of developing country cereal production is grown on irrigated land. Impending water shortages in North China may well be so great by 2025 that China may have to import some 300 million metric tons of grain per year to meet the demand arising out of population and income growth.

The area irrigated by using tube wells to pump groundwater has expanded quite rapidly. In many ways, pump irrigation from aquifers is an ideal form of irrigation since the water is stored underground with no loss from evaporation. The water can be used during the dry season when reservoirs for surface irrigation may dry up.

One very common problem of surface water systems is waterlogging and salinity resulting from excessive water use and poorly-designed drainage systems. Another common practice relates to extraction of water from aquifers in excess of recharge, resulting in lowering of the groundwater level and rising pumping costs. These spillover effects are sometimes sufficient to offset the contribution of expansion of irrigated area to agricultural production.

Climate Change

In the 1950s, it emerged that carbon dioxide (CO_2) was increasing in the atmosphere. In the late 1950s, computer model simulations indicated possible changes in temperature and precipitation that could occur due to human-induced emission of CO_2 and other greenhouse gases into the atmosphere. By the 1980s, it was generally agreed that energy production from fossil fuels could, by 2050, result in a doubling of the atmospheric concentration of CO_2, a rise in global average temperature by 1.5–4.5°C, and a complex pattern of global climate changes. Any increase in the atmospheric concentration of CO_2 can affect agricultural production in the following ways:

(1) It may have a positive effect on the growth rates of crop plants (and weeds) through the CO_2 fertilization effect and by decreasing the rate of transpiration.

(2) It would raise the temperatures which could lead to a rise in the sea level, resulting in inundation of coastal areas and intrusion of salt water into groundwater aquifers and surface waters. Low-lying coastal agricultural areas in Bangladesh, for example, may be impacted severely.

(3) It may change temperature, rainfall, and sunlight regimes. The resulting effects may vary greatly across agroclimatic regions. However, greenhouse-induced warming is likely to be greatest in high mid-latitude regions (>45°) and high latitudes (>60°). Subtropical and tropical regions will experience less extreme temperature changes. Monsoon rains are

likely to penetrate further northward. Northern areas in which production is currently limited by a short growing season could expect both higher yields and an expansion of area devoted to cereals and forage plants (Ruttan, 1999).

There has been a substantial change in estimates of the impact of global climate change on crop yield and agricultural production which may range from slightly negative to slightly positive (Rosenzweig and Hittel, 1998).

Not much attention has been given to the indirect or interactive effects of climate change. The few assessments made so far suggest that, as environmental stress intensifies as a result of warmer climates, crops will become more vulnerable to weeds, insects, and plant diseases (Rosenzweig and Hittel, 1998). The incidence and severity of soil erosion, changes in rainfall, surface water storage, groundwater recharge, incidence of pests and pathogens, or frequencies of extreme events, such as drought, floods, and climate variability, have not been included into the climatic change models (see Rotmans and Dowlatabadi, 1998).

According to Ruttan (1999), soil loss and degradation will probably not be a serious constraint on global agricultural production over the next half century. But this could become a serious constraint on production on a local or regional scale in some fragile resource areas.

Also, it is unlikely that lack of water resources will become a severe constraint on global agricultural production in the foreseeable future. But in 50–60 of the world's most arid countries, plus major regions in several other countries, competition from household, industrial, and environmental demands may promote reallocation of water away from irrigation. In some countries, the reduction in irrigated area will be large enough to bring down agricultural production. According to Ruttan (1999), while the constraints we have stated do not threaten global food security, they may, individually or collectively, pose a threat to growth of agricultural production at the regional and local level in many of the world's poorest countries. This means that the transition to agricultural sustainability may depend on the maintenance and enhancement of capacity for technical and institutional innovation.

FOOD SELF-RELIANCE IN DEVELOPING COUNTRIES

According to FAO (1995), per capita food availability in the developing world has increased by 20% since the early 1960s, and the world now has more than twice as many people but 150 million fewer hungry people than in 1960. Global agricultural production may continue to at least match growth in food demand over the next decade, assuming no major weather anomalies. But there are still 800 million hungry people and 185 million preschool malnourished children in the developing world. The likely future global adequacy may come largely from excess capacity in the industrialized countries. Whereas some developing countries such as South

Korea and Malaysia will be able to import food, Thailand will even export food. But in many African countries, per person food output has fallen. In most Latin American countries and also India, income and overall food availability are fairly adequate, but a highly skewed distribution of land keeps many rural people in poverty despite a regional average income many times higher than in Africa.

Asia has had the most rapid growth in per capita food production. In the past 25 years, the proportion of hungry people in East Asia fell from 41% to 16% even while population rose by 500 million. With a projected population of nearly three billion by 2050 and rapid per capita income growth, its food needs will continue rising in the coming decades. Latin America may keep pace with food demand but at the expense of further destruction of its natural forests which are the most extensive in the world (Herdt, 1998).

Development requires increased productivity of agriculture in the underdeveloped countries. When advanced countries help less advanced ones to increase their food production capacity, it does not mean that the agricultural exports or trade of the advanced countries will suffer. In developing countries when agricultural growth rates are high, general economic growth is high, and their total imports also rise. In fact, when poor countries grow rapidly, their demand for food usually grows more rapidly than they can meet it. When countries reach high income levels, their food demand grows much more slowly (Herdt, 1998).

Developing countries are largely agricultural. Their development must come largely from their agricultural sectors. Those countries that tried to first develop an industrial sector have failed, or only seemed to succeed for as long as the agricultural sector was being taxed to subsidize the industrial sector.

The world's affluent consumers must ensure adequate rates of food production growth in the rest of the world, especially in the 'big' countries such as Russia, China, and India. If any of these countries is unable to meet the bulk of its future food needs domestically, the adverse effects on equity and the impact on world food availability are likely to be strong.

Food self-reliance means the ability to produce most of the food a nation needs and to buy the rest with export earnings. It is necessary because rich nations will give food only as long as they themselves have surpluses. In the coming years, such food donations may be available only in specific crises, so it is wise for nations to aim for self-reliance.

Some people believe that appropriate technology may make positive contributions in the developing world with relatively small investments in research. The Green Revolution of the 1960s and 1970s demonstrated that plant genetic improvements flow quickly to many farmers, benefiting them as well as consumers. Rising agricultural productivity has been the key to economic growth and development in every country that once used to be poor with a high proportion of its population dependent on farming. The most difficult challenges are in countries where cropland is being fully used, e.g., India and China. Their crop yields must be increased to increase output. No doubt, raising crop yields is a big challenge, but the sustainability of the systems being developed is also globally important. According to Herdt (1998), high-yielding seeds and fertilizer are essential for sustainably improving productivity and well-being. However, a few practices that have been promoted in the past, such as broad spectrum pesticides and continuous planting of a single crop, are not good. Means of assessing the longer term questions need to be developed and applied to ensure that practices that give high yields in the short run (but falling yields and incomes in the long run) are not encouraged.

The first modern semidwarf improved varieties of rice were released in 1965 by the International Rice Research Institute (Manila) and by 1990 these high-yielding varieties covered 100% of East Asia's rice area and upto 90% of the rice area of most other Asian countries (Pingali *et al.*, 1997). Since 1965, Asian rice yields have increased from 2 tons/hectare to 3.5 tons/hectare.

Large-scale industrialization of fishing and the global fishery market have put heavy pressure on marine biodiversity. Overfishing, introduction of new species, restocking, and aquacultural development have seriously affected diversity in continental waters. Both at sea and inland, small-scale fishing communities and the poor people have to suffer for the scarcity of resources. International conflicts over fishing rights have also increased because fish is a dwindling resource due to the explosive growth of the amount of fish which is being harvested out of the water. The current fisheries situation is far from sustainable. In a report issued in June 1994, the FAO stated that 69% of the global fish stocks for which assessments are available are either fully exploited, overfished, depleted or slowly recovering from depletion. However, the figure of 69% actually masks regional differences: in the Northern Pacific, nearly 100% of the studied fish stocks fall in those categories, and more than 60% in the Eastern Atlantic. By 1992, FAO had recorded 16 major fishery species whose global catch had declined by more than 50% over the previous three decades. At least nine of the world's 17 major fishing grounds are now in precipitous decline, and four have exhausted totally from a commercial point of view. In several areas, under current exploitation patterns, enough fish is not being left in the water to regenerate their stocks (FAO, 1992, 1993a).

All this has happened mostly because of a tremendous increase in the size of the global fishing fleet. Between 1970 and 1989, fishing fleets grew at twice the rate of fish landings. In 1993, there were 1 million large-scale (more than 24-m-long) and 2 million small-scale fishing boats operating around the world. Some have felt that one way to solve the problem of overfishing is simply to reduce the number of fishing boats, preferably the smaller ones. Technology is also a crucial factor in overfishing. Large, modern fishing vessels started incorporating improved self-positioning, fish-detection, fish-aggregation, fish-catching, and on-board fish-preservation technology. This increased their ability as efficient hunting machines competing for scarcer fish. Yet another factor is the policy of many countries to subsidize their national fleets in a race to continue the depletion of marine biological resources. In some cases, surplus fishing vessels in developed countries have been exported or dumped in developing countries.

A variety of human activities threaten aquatic biodiversity. Uncontrolled dumping of toxic waste, unsustainable tourism, dam construction, nutrient discharges from intensive agriculture, and population concentration are just some. But fisheries and aquaculture are the biggest threat to marine biodiversity, and a serious menace to continental aquatic ecosystems. Many fish species have reached the verge of extinction by fishing activities, long-living and slow-reproducing species being particularly vulnerable. The living fossil coelacanth, the common skate, and several species of shark are endangered. Some sessile species, e.g., giant clams, have also been decimated by fishing.

Overfishing can affect fish populations in various ways. If a fishery targets a high value species, the fleets may deplete, or even cause collapse of, the fish stocks. At these low levels, the populations are far more sensitive to environmental changes (Table 4.8). Fisheries-induced collapse of a marine population may have two consequences for biodiversity, viz., (1) the population may fail to recover and recolonize its ecological niche or (2) rare genes may be lost.

Indiscriminate fishing can be disastrous for non-target species as well. Some one-quarter to one-third of all caught fish in commercial fisheries is being thrown back into the water because they are deemed to be undesirable for some reason.

Marine mammal, turtle, and bird populations are also damaged by fisheries due to their long lifespan and low fecundity.

Overfishing strongly depletes prey species populations. Some of the small fish species at the lowest level of the marine trophic web are the sand eels, anchovies, pilchards, capelin, and krill. Their overfishing leads to the decline of other fish stocks which depend on them (e.g., predator species cod and haddock).

IMPACT ON BIODIVERSITY

Fisheries also adversely affect biodiversity through the degradation of marine habitats. When the widespread dynamite fishing is practised in coral reefs—one of the most diverse ecosystems in the world—it not only kills fish but also damages and degrades the reef. Likewise, trawling in shallow waters is a common practice in many parts of the world. Shallow waters host some of the most complex and diverse marine ecosystems. The destruction of sea grasses (*Posidonia oceanica*) in the Mediterranean Sea (a refuge for juveniles of fish species) exemplifies habitat degradation. Shrimp trawling in shallow waters also erodes the seabed.

Table 4.8 Examples of fishery collapse and its impacts

Fishery collapse	Impact	
	Environmental	Social
Spring spawning herring and capelin (Barents Sea)	Starvation of cod Starving seals died and entangled in coastal nets Marine birds starved to death	Cod fisheries crises Marginalization of Norwegian fishing communities from access to cod fisheries Loss of coastal nets
Coastal fisheries, Kerala, India (mid-70s)	Disappearance of some sea-bottom species from fishermen catches	Impoverishment of artisanal fishermen, decreased access of the poor to fish
Overfishing of most of exploited demersal species, e.g., northern cod	Starvation of whales, seals, and marine birds, resulting in larger migrations and reproductive failure	Loss of more than 50,000 jobs in fishery itself, plus many more in related industries and activities
Anchovy fishery, Black Sea (1989)	Black Sea ecosystem changed	Loss of thousands of jobs and livelihood resources

Overfishing in closed systems (rivers or lakes) may have a greater impact on genetic diversity than in the open seas (see Smith, 1995; Prat, 1995; FAO, 1992, 1993a). Figure 4.6 compares relative per capita fish consumption in the developed and developing countries.

Introduction of new species by man in closed lacustrine systems for aquaculture or fishery enhancement has caused enormous losses of biodiversity. In the 1950s, the Nile perch was introduced in Lake Victoria for sport fishing. Its voracity and large size led to the extinction of at least 200 smaller indigenous species (Prat, 1995).

Intensive shrimp aquaculture also has a profound and direct impact on marine biodiversity. In Thailand and Ecuador, it has resulted in the loss of extensive coastal mangrove forests in order to build ponds. Half of the world's mangrove forests have already been cut down, with aquaculture being the lead cause. In some countries, larval fisheries use chemicals that kill some other species in the mangrove forests, including the mangroves themselves.

After discussions at several fora and various groups, the following notable points have emerged in relation to fisheries:

(1) Priority should be given to artisanal fisheries in view of their social relevance, and as a means of promoting environmental protection.

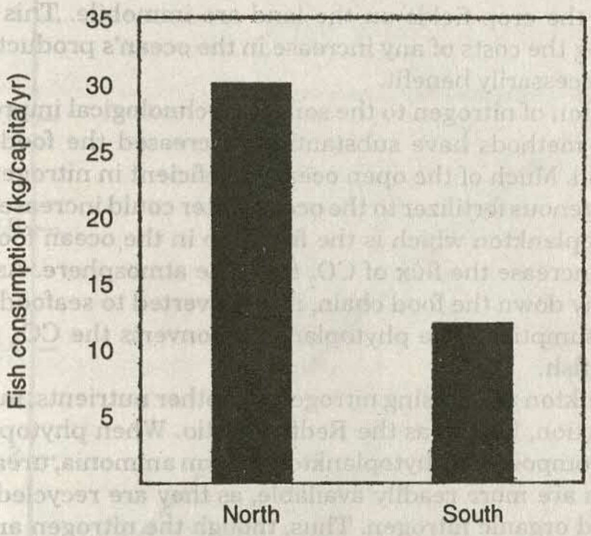

Fig. 4.6 **Relative per capita fish consumption in the North and the South (after Prat, 1995).**

(2) Fisheries should be managed in ecologically and socially just manner, respecting cultural, biological, and ecosystem diversity.

(3) Access to fishery resources should be based on equitable principles and not on political might or technology.

(4) The management of fisheries and the aquatic environment should include the full and meaningful participation of fisherfolk, NGOs (non-governmental organizations), and scientists.

ENGINEERING A SUSTAINABLE WORLD FISHERY

Three important and interconnected problems facing mankind today are those of increasing population, provision of adequate food, and increasing level of waste carbon dioxide in the atmosphere. The ocean provides annually about 90 million tons of high protein food and absorbs some 1000 million tons of carbon dioxide from the atmosphere. By the year 2100, the world population is expected to more than double its 1990 level of 5.2 billion and will approach 11.5 billion, most of the increase occurring in the developing countries.

The 1996 World Food Summit held in Rome estimated that 800 million people already suffer from chronic undernourishment, and this number will rise unless global food production is more than doubled by the year 2100. This calls for new methods of protein production.

While the capacity of the land to produce increased crop yields has been improved in recent years, the same has not been achieved for the oceans, possibly in view of the different organization of economic activities into sovereign states in the two cases: whereas fish migrate across national boundaries, the crop fields on the land are immobile. This means that those bearing the costs of any increase in the ocean's productive capacity would not necessarily benefit.

The addition of nitrogen to the soil and technological improvements to agricultural methods have substantially increased the food production from the land. Much of the open ocean is deficient in nitrogen. The addition of nitrogenous fertilizer to the ocean water could increase the production of phytoplankton which is the first step in the ocean food web. This would also increase the flux of CO_2 from the atmosphere. As the carbon works its way down the food chain, it is converted to seafood suitable for human consumption. The phytoplankton converts the CO_2 through the food web to fish.

Phytoplankton grow, using nitrogen and other nutrients, in a fairly constant proportion, known as the Redfield ratio. When phytoplankton die, bacteria decompose the phytoplankton to form ammonia, urea, and amino acids, which are more readily available, as they are recycled faster than the dissolved organic nitrogen. Thus, though the nitrogen and phosphorus from upwelled waters occur in the suitable Redfield ratio, the surface waters contain less nitrogen (than Redfield) than is needed by phytoplankton. Therefore, nitrogen appears to limit net primary production in most marine situations (Howarth, 1988).

The ocean biomass is distributed very unevenly. The coastal parts are over 100 times more productive than the nitrogen-starved central ocean. Enriching the open ocean regions with low concentrations of nutrients would ensure that just modest increases of phytoplankton occur over large areas, in turn increasing fish production. The nutrients could be supplied by pipelines from shore to be swept into the ocean gyres by the prevailing current, and mixed by turbulence.

Based on the Redfield ratio, Jones (1996) assumed that 1 ton(t) of C fixed by new primary production requires 1/7 t of nitrogen, and that this nitrogen can be supplied with a 70% uptake efficiency. Thus, the addition of 1 t of nitrogen might increase new primary production by 5 t C. If the current level of new production is taken to be roughly 4.5 gigatons (Gt) C yr^{-1}, then the nitrogen needed for production to keep pace with population may be expected to increase to about 0.8 Gt N yr^{-1} in the year 2060 (Fig. 4.7). Since the weight of seafood at present taken from the ocean is only 0.08 Gt yr^{-1}, this has a negligible impact on the new primary production of 4.5 Gt C yr^{-1}. Fish harvesting at this level does, however, exert some impact on the ocean ecology.

Around the world some efforts are underway to reduce uncontrolled nutrient discharges into the ocean, in response to local eutrophication. These should not be confused with intentionally raising the nutrient level in the nitrogen-deficient areas.

With annual fish landings of about 80 million tons and with new primary production of about 4.5 Gt C, a linear relationship suggests that an

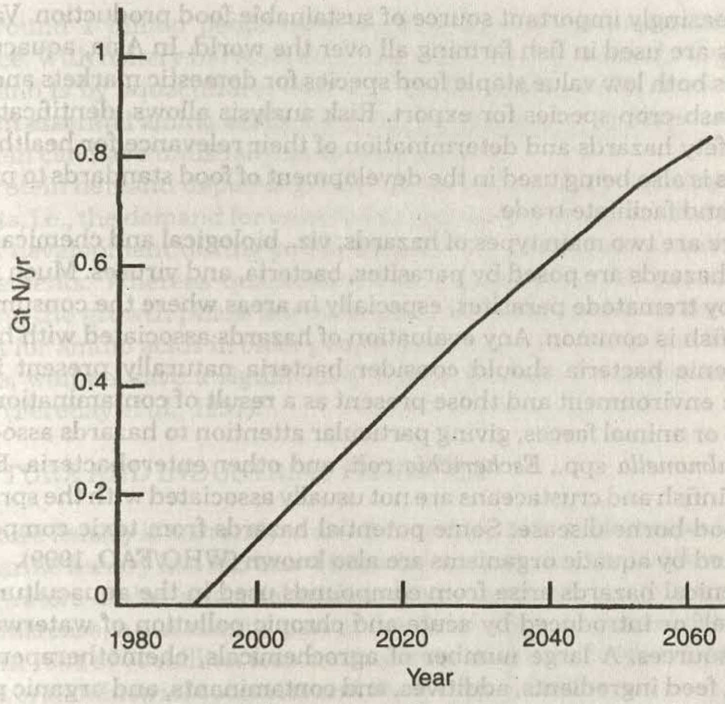

Fig. 4.7 Additional nitrogen needed to keep fish catch per head of population constant, assuming new primary production in the ocean is about 4.5 Gt C annually. The level of nitrogen manufactured (as up to 1995) is about 80 million tons per year.

increase of primary production by 1 t C will increase fish landing by about 18 kg.

Our current practice of exploiting the fish stocks of the ocean without ocean enrichment has already crossed the sustainable limit. Fish stocks of aggressively harvested species are collapsing. Mild enrichment may provide an opportunity to both sequester the excess CO_2 of the atmosphere and provide additional protein for the rising world population.

AQUACULTURE

There are several risks to human health from the consumption of farmed finfish and crustaceans, which need to be identified and controlled in view of the growing importance of farmed fish as both a major export commodity and a vital source of protein in low-income food-deficit countries. Particular attention is warranted in Asia where 90% of global aquaculture production takes place. Common fish farming practices, associated risks, and strategies for their control need to be considered for small-scale rural subsistence farms as well as for intensive commercial systems.

Aquaculture is one of the fastest growing food sectors in the world and an increasingly important source of sustainable food production. Various systems are used in fish farming all over the world. In Asia, aquaculture supplies both low value staple food species for domestic markets and high value cash-crop species for export. Risk analysis allows identification of food safety hazards and determination of their relevance for health. Risk analysis is also being used in the development of food standards to protect health and facilitate trade.

There are two main types of hazards, viz., biological and chemical. Biological hazards are posed by parasites, bacteria, and viruses. Much risk is posed by trematode parasites, especially in areas where the consumption of raw fish is common. Any evaluation of hazards associated with human pathogenic bacteria should consider bacteria naturally present in the aquatic environment and those present as a result of contamination with human or animal faeces, giving particular attention to hazards associated with *Salmonella* spp., *Escherichia coli*, and other enterobacteria. For viruses, finfish and crustaceans are not usually associated with the spread of viral food-borne disease. Some potential hazards from toxic compounds produced by aquatic organisms are also known (WHO/FAO, 1999).

Chemical hazards arise from compounds used in the aquaculture system itself or introduced by acute and chronic pollution of waterways or water sources. A large number of agrochemicals, chemotherapeutants, metals, feed ingredients, additives, and contaminants, and organic pollutants all can cause risk. Since the risk of infectious disease is an ever-present problem in aquaculture, particular attention needs to be given to potential health effects arising from the use of antimicrobial agents, the presence of residues in edible fish tissue, and the possible development of antimicrobial resistance.

Strategies for controlling biological and chemical hazards are based on certain principles of the Hazard Analysis Critical Control Point System, adapted to aquaculture. To illustrate these principles, four critical control points in an aquaculture system deserve focus: site selection, water quality, feed supply, and fish production.

According to Delgado *et al.* (1995), an average person of the developed world consumes 100 kg of meat and fish and 178 kg of milk equivalent per year, whereas the corresponding figures for the less developed world are 29 kg and 31 kg, respectively.

High value nutrients achieve high income elasticities in all developing countries, particularly in the threshold countries. Therefore high value nutrients are much sought after and their demand rises disproportionately with income (Becker and Focken, 1998). The only growth sector within the fishing industry at present is aquaculture, with production increases averaging 10% since the early 1980s. Its share in total fish production today is approximately 20%. However, aquaculture yields will continue to grow only if production can be maintained sustainably. A major objective is to ensure that low income households also have access to high value protein.

Around 1 billion people now depend on fish as their chief protein source. With fishery harvests declining, the only way to satisfy the growing demand is by aquaculture. Over 100 million people suffer from deficiencies in essential amino acids. For these people, even small amounts of fish protein can have unusually favourable effects.

Protein demand depends greatly on the subject's age. Quality requirements, i.e., the demand for essential amino acids that are needed for structural development during youth, initially run parallel to quantitative requirements. Whereas quantitative recommendations for protein intake during the growth phase are quite well established, data on the requirement for amino acids in older people are meagre. It seems that beyond 65 years, women have a significantly higher demand for amino acids than men (Fereday *et al.*, 1997).

CAPTURE AND INDUSTRIAL FISHERIES

Capture fishery is currently at an all-time high of 90 million tons. The yield of marine fishery has increased tremendously during the last few decades. The waters of the industrial nations have contributed only marginally to this increase, a substantial part of the developing countries' fish production in 1994 of 70 million tons coming from the long-distance fishing fleets of several industrial countries and the former USSR.

But fishing fleets inflict serious damage on marine ecosystems, in coastal regions, and on peasant fisherfolk. A fraction of unwanted, incidental catch is thrown back into the sea rather than being used (e.g., as a protein source for low income groups and a protein supplement for farm animals). Other, indirect effects of capture fishery often have a strong impact on marine ecosystems.

Any long-term sustainability of the current fishery harvests will require rigorous management of the world's oceans. The demand for seafood in the year 2025 is expected to be of the order of 115 million tons, regardless of which of the UN's population scenarios (11.9 or 9.8 or 7.9 billion people by the year 2050) is used as a basis (Forteath, 1997). This additional demand cannot be covered solely by capture fishery. Aquaculture will have to contribute an additional 19 million tons by the year 2010. Alternative estimates predict a total demand of 55 million tons of aquaculture products in 2025 (Forteath, 1997).

More than 500,000 tons of high value fish (*Salmo salar*) are being produced annually. Norway's production from net cages exceeds 300,000 tons today.

In the future, it will be necessary to ensure that the environmental risks from these capital-intensive aquaculture systems are reduced, e.g., by reduction of stocking density and use of natural, wholly degradable agents against disease.

In the tropics, although the production of crustaceans is just less than 1 million tons, accounting for no more than about 5% of total production, in monetary terms, its share in 1994 was 20%, at that time equivalent to almost $7 billion. World shrimp production is currently more than 850,000 tons and is being almost exclusively exported to the industrial world. Developing countries today earn more foreign exchange from fish and shrimp exports (approximately $17 billion) than they do from all the well-known 'cash crops' such as sugar, coffee, tea, and cocoa taken together (Becker and Focken, 1998).

Industrial fishery and capital-intensive aquaculture are currently destroying natural habitats which could otherwise be serving as a food resource for the poorer classes in tropical countries. The developing world offers ideal conditions for semi-intensive culture systems.

In intensive systems, fish production is largely controlled, and growth is virtually entirely governed by concentrate feeding. By contrast, extensive and semi-intensive operations largely rely on internal inputs. These management systems do not compete with humans for food resources. Their trophic status resembles that of ruminant production in arid and semiarid regions of the tropics and subtropics. They rely on internal nutrient sources such as animal dung, plant residues, and cropping by-products. Pond yield depends on the quantity and ratio of nutrients and on the application regime, ranging between a few thousand kg ha^{-1} y^{-1} and several thousand kg ha^{-1} y^{-1}. A special type of management system is the integration of plant (e.g., rice) cropping, animal husbandry (ruminants, monogastric stock), waterfowl (e.g., ducks and geese), and fish. Such systems make optimum use of all internal resources and provide a basis for nutritional as well as financial subsistence (Gupta *et al.*, 1997).

NUTRITIONAL GENOMICS

In the past two decades, genetic engineers have produced plants that resist disease and tolerate herbicides, plants that produce drugs, and even some plants that make plastic. Now they are attempting to alter plant genomes so that the plants can be enriched in vitamins and minerals. For instance, attempts are underway to coax plants to make more vitamin E in a form that the human body can easily use, while other projects are interested in vitamin A and iron. The market for such fortified plants might be health conscious consumers who dislike taking vitamin pills, or those in the developing world who lack access to the necessary micronutrients (Mlot, 1998).

Vitamin E is essential to keep blood cells and neurons functioning and possibly may help protect against cancer and heart disease. Some work has been done on *Arabidopsis* to increase its production of the most useful form of vitamin E, a ring and chain of carbon known as α-tocopherol. *Arabidopsis* seeds normally produce γ-tocopherol, one enzymatic step short of α-tocopherol. The gene responsible for that key enzyme has been looked for by scanning through the sequenced genome of the cyanobacterium *Synechocystis* for a known gene that functions earlier in the pathway.

Nearby genes were tested until the one that codes for the enzyme γ-tocopherol methyltransferase was found. Finally, in the growing database of *Arabidopsis* genes, the required version of the gene could be found lurking unexpressed in the plant seeds. This gene was then hooked to a regulatory sequence that specifies expression in the plant seed and the whole package was engineered back into developing *Arabidopsis* plants. The result was a 10-fold increase in the amount of α-tocopherol in the seeds. The offspring of the first-generation plants also produced more vitamin E in their seeds (Mlot, 1998).

The next step would be to similarly engineer a food plant such as soybean which already makes a small amount of α-tocopherol in its seed.

Plants expressing increased amounts of other micronutrients may not remain far behind. Work has started to engineer rice to produce vitamin A, using genes from bacteria and daffodils, which make the carrot-coloured carotenoids that provide vitamin A. If successful, vitamin A-rich rice could help alleviate deficiencies in rice-eating people.

Iron is the commonest nutritional deficiency worldwide. Iron-fortified plants have not been engineered as yet but an *Arabidopsis* gene that codes for a protein that allows the plant to take up iron from the soil has been identified. Similar group of transporters has been found for zinc, another essential micronutrient. Manipulating these transporter proteins may help boost the amount of minerals a plant takes in. Such work may one day produce fortified crops or vegetables for use in developing as well as developed countries (Mlot, 1998).

BIOTECHNOLOGY AND HUMAN NUTRITION

The last five decades of agriculture chiefly focused on meeting the food, feed, and fibre needs of humans. This was made possible through the development of economic, chemical processes to reduce nitrogen to ammonia and the use of nitrogenous fertilizers in agriculture, plant breeding for hybrid crops, resulting in a global green revolution, and finally, by the discovery and use of chemical pesticides to control pests, weeds, microbes, and insects. Intensive agriculture today fully exploits these advances and is also benefited by superior irrigation techniques and better tillage systems. Global cereal yields practically doubled between 1960 and 1990. Yields of both rice and wheat crops have increased greatly (Kishore and Shewmaker, 1999). These agricultural technologies, however, may not keep pace with projected population increases. So the challenges for the next few decades go far beyond simply addressing the needs of an ever-growing global population. Besides producing more food, agriculture will have to deal with declining resources such as water and arable land. It will need to enhance nutrient density of crops, and achieve these and other goals in a manner that does not degrade soil and environment. Biotechnology and other emerging technologies can be useful tools to help meet these multidimensional challenges.

We will need several new and improved technologies that can strengthen infrastructure to help address the challenges ahead. We have already entered a new era of breakthrough technologies. Termed the information revolution, this era is sure to have a tremendous impact on society. Information-driven agriculture will have two components, viz., (1) information based on genomics, the study of genes, which is an enabling link across life sciences, including agriculture, food and nutrition, and pharmaceuticals; and (2) information that is based on the current silicon revolution. Computer and modern electronic communication systems can be applied across the life sciences to enhance value. Already in agriculture, farmers are taking advantage of the system for precision agriculture that optimizes inputs, characterization of outputs so that they can match the needs of their customers with specific products as well as managing their business based on real-time information (Kishore and Shewmaker, 1999; Cassman, 1999).

Every important crop can be genetically modified. Plant biotechnology can substantially augment traditional plant breeding. It is expected that plant biotechnology will soon traverse three phases of development, viz., agronomic trait development, differentiated crop development, and use of plants as factories (Kishore and Shewmaker, 1999).

Agronomic traits that are attracting attention are mainly input traits (mostly single-gene traits). In contrast, differentiated crops are focused on either grain quality or output characteristics.

Traditional plant breeding could produce many differentiated crops such as canola vs. high erucic- and glucosinolate-containing rape; waxy and high amylose maize vs. yellow dent corn; basmati vs. long grain rice; and durum wheat vs. regular wheat. Biotechnology can help create differentiated, value-added products that create value downstream of production. Some such differentiated crop offerings (e.g., high-oil corn) are already appearing in the market-place.

The idea of using plants in place of chemical or nutrient factories to supply food, feed, and fibre is attracting attention and constitutes the first step toward biotech-based, nutritionally-fortified foods (Bronner, 1995; Kishore and Shewmaker, 1999). One good example is high carotenoid canola, rich in β-carotene—a precursor to vitamin A.

Indeed, biotechnology has a great potential to enhance value across the system from crop to farmer, customer, and consumer. It is already enhancing the quality of food. It can improve the sustainability of production systems by requiring fewer inputs to control pests and better protect the quality of water and lands around us. Biotechnology has a substantial role in health care of humans and in improving their nutritional status (Kumar, 1998; Kishore and Shewmaker, 1999). As we look at food production in a more holistic way, biotechnology will be an important component of that holistic system.

PLANT NUTRIENTS FOR HUMAN HEALTH

For maintaining sound health, humans require a diverse, balanced diet containing a mixture of macronutrients and micronutrients. The bulk of the diet is made of carbohydrates, lipids, and proteins (i.e., macronutrients) which are used primarily as an energy supply. Micronutrients are organic or inorganic compounds present in small amounts. Though not used for energy, micronutrients are nonetheless essential for good health. Essential micronutrients in the human diet include 17 minerals and 13 vitamins required at minimum levels to alleviate nutritional disorders (Table 4.9). Besides these, there are certain non-essential micronutrients encompassing several unique organic phytochemicals that are not strictly required in the diet, but when present at sufficient levels somehow promote good health (DellaPenna, 1999).

Table 4.9 Some essential micronutrients in human diet and their daily requirements and safe upper intake levels (after DellaPenna, 1999)

Nutrient	Maximum adult RDA*	Safe upper intake (relative to RDA)**
Calcium	1200 mg	2×
Iron	15 mg	5×
Iodine	150 µg	13×
Selenium	70 µg	13×
Vitamin C	60 mg	16×
Vitamin B_6	2 mg	125×
Folate	200 µg	50×
Biotin	30–100 µg	300×
Vitamin E	10 mg α-TE***	100×
Vitamin A†	1 mg RE††	5× (retinol) 100× (β-carotene)

*Recommended dietary allowance per day. Values presented are highest RDA for male or female adults, excluding pregnant or lactating women (see Ziegler and Filer, 1996; Food and Nutrition Board, 1989).

**The safe upper intake limit, excluding pregnant or lactating women, is associated with a low probability of adverse side-effects and assumes individual variation in requirements and tolerance to high levels. However, intake of supplements at these levels is not recommended or desirable routinely for healthy individuals (because excessive dietary intake can cause adverse side-effects).

***One α-TE (α-tocopherol equivalent) is equal to 1 mg of (R,R,R,)-α-tocopherol.

†Vitamin A (retinol) is not made in plants; however, plants contain a number of provitamin A carotenoids (for example, β-carotene) that can be metabolized to vitamin A.

††Vitamin A activity is expressed in retinol equivalent (RE). One RE is equal to 1 mg of *trans*-retinol or 12 mg of other provitamin A carotenoids.

Unfortunately, basic nutritional requirements for much of the world's population are still unsatisfied. Many people in developing countries live on simple diets composed primarily of a few staple foods (e.g., wheat, rice, and corn) that are poor sources of some macronutrients and many essential micronutrients. Consequently, the diet of over 800 million people lacks adequate amounts of macronutrients and essential micronutrients (Calloway, 1995). Some 250 million children are at risk for vitamin A deficiency which can cause blindness. Two billion people are at risk for iron deficiency and 5 billion people suffer from iodine deficiency (see DellaPenna, 1999). Even in industrialized nations, micronutrient deficiencies are quite common, owing to poor eating habits.

Plant micronutrient levels often vary widely. Many important crops contain insufficient concentrations of many essential vitamins and minerals to satisfy the recommended dietary allowance (RDA); therefore, nutrient fortification of the food supply becomes necessary. RDAs can also be somewhat misleading because they are not the levels needed for optimal health, but rather the minimum levels needed to alleviate specific nutritional disorders. RDAs do not reflect the current knowledge (Ziegler and Filer, 1996; Food and Nutrition Board, 1989) that the higher intake of some vitamins and minerals (e.g., vitamins E and C, carotenoids, and selenium) can reduce the risk of certain cancers, cardiovascular diseases, and chronic degenerative diseases (see DellaPenna, 1999). To provide such therapeutic levels in the diet, additional fortification of the food supply is required.

MICRONUTRIENT TARGETS

To ensure an adequate dietary intake of all essential vitamins and minerals, there is now renewed interest in the study and manipulation of plant secondary metabolism. Attempts are underway to identify and isolate genes required for the synthesis and accumulation of a target compound, so that its levels might be modified in staple crops. Unlike macronutrients, which account for up to 30% of a tissue's dry weight, individual micronutrients are much less than 0.1% of a tissue's dry weight and hence significant increases in micronutrient levels are theoretically feasible (DellaPenna, 1999).

Four minerals (iron, calcium, selenium, and iodine) and four vitamins (folate, vitamins E, B_6, and A) definitely play a role in maintenance of optimal health, but are limiting in diets worldwide. The upper safe levels of intake for these four minerals are 2–13 times the RDA, while for the four vitamins, they are generally much higher. The notable exception is vitamin A (retinol), which often causes side-effects at five times the RDA. Plants synthesize only provitamin A carotenoids, which act as substrates for retinol synthesis by humans. The upper safe intake level for β-carotene (the most active provitamin A carotenoid in plants) is 20 times that of retinol or 100 times the RDA for vitamin A. Therefore, it is wiser to manipulate provitamin A carotenoid synthesis in plants, rather than go in for retinol synthesis.

BALANCED NUTRITION FOR GOOD HEALTH

Many of the problems resulting from improper nutrition can be avoided if one follows the eight simple principles now outlined:

(1) Variety in food is the key to good health. A balanced diet should include moderate amounts of cereals, vegetables, and fruits.

(2) The food should include all the six natural tastes, viz., pungent, bitter, sweet, astringent, sour, and salty. The food should contain proteins, carbohydrates, fats, oils, minerals, and vitamins.

(3) As there is no single complete food, it is necessary to take food items of several different types—the items may be rotated on different days or times.

(4) Anything in excess is harmful. Moderation is best. Intake of sugar and salt should be kept as low as possible.

(5) The daily diet should preferably have one red item (e.g., carrot, tomato, papaya which contain lycopene), two green items (e.g., spinach, cabbage, capsicum), five dry fruits in small amounts, a few teaspoonfuls of oil (liquid at room temperature), some garlic, soya, oats if possible, one small cup of pulses (or lentils), wheat, and rice.

(6) Many plants contain non-essential but specific phytochemicals (secondary metabolites) that can be useful nutritional supplements in human diet. Fruits and vegetables contain antioxidants (e.g., vitamins C and E, β-carotene, and selenium). Antioxidants destroy free radicals in the body—the free radicals, if not neutralized, damage cells and tissues. There are four broad categories of phytochemicals that have been found to be the chief reason that plant-rich diets are associated with lower morbidity and mortality in adult life. These four classes are (a) carotenoids (e.g., lycopene in tomato, lutein in spinach); they help ameliorate or prevent prostate and oesophageal cancer, cardiovascular disease, and macular disease; (b) glucosinolates (e.g., glucoraphanin found in broccoli); they ameliorate or prevent several cancers; (c) phytoestrogens (e.g., genistein and daidzein, found in soybean and soy products); they ameliorate or prevent osteoporosis, cardiovascular diseases, and cancers of prostate, breast, and colon; and (d) phenolics (e.g., resveratrol, found in red grapes); they ameliorate/prevent cancers and cardiovascular diseases.

(7) Natural, seasonal foods should be preferred to preserved and unseasonal foods. Raw and light-boiled vegetables are better than overcooked vegetables provided that they are thoroughly washed with clean water or dilute vinegar. Root vegetables are good in small amounts provided that they have been properly peeled to remove all adhering sand or soil particles and then washed in clean water.

(8) Alkaline foods (e.g., most fruits and vegetables, even citrus fruits

and lemons) should constitute the bulk (about 75%) of the diet. Acidic foods (wheat bread, rice, fried items, coffee, tea, pickle, etc.) should make up no more than 25% of the diet.

5

Transportation and Mobility

INTRODUCTION

Thousands of millions of people in the developing world walk to work, their business or marketing every day. Their lot could be greatly improved by some form of transport. To poor people, even cycling means a leap forward as it eases their capacity to earn livelihood.

Cars and lorries offer immense benefits in longer distance transport and trains and buses have advantages in terms of public mobility. While non-motorized transport is a good alternative in a large variety of contexts, there are clearly many cases where motorization brings huge advantages for local communities.

Sustainability is a complex and crucial issue in the transportation sector especially when it comes to securing people's livelihoods. The track record of road- and railway-building and the quality of services related to/dependent on road/rail transportation in the developing countries is certainly not up to the mark.

For the majority of people in a low income country (LIC), personal cars are unaffordable and motorized transport services are either non-existent, qualitatively poor, or too expensive to be used on a daily basis. Also, good roads do not exist, so the dominant mode of transport for most poor people is walking.

In rural areas, people frequently walk long distances for water and energy and to reach workplaces, employment or social services. Walking is slow. It constrains access to markets, agricultural inputs, credits, information, education, and health services. It consumes considerable time and energy.

On the other hand, whilst many city dwellers rely on walking as their primary means of transportation, huge investments are made on roads which benefit only the few people who own motor vehicles.

Also, the increasing pollution levels in urban areas need to be checked by investing in more sustainable urban transportation alternatives. Land use patterns should aim at developing a city of 'short distances' rather than pushing more and more urban residents to the periphery.

Globally, CO_2 emissions from motor vehicles have been threatening the environment. The motor vehicle population has been growing rapidly in every newly industrialized country (NIC).

In rural areas of India, 73% of the weight and 55% of the ton-kilometres are transported by animal or human power (Sieber and Kipke, 1998) (Fig. 5.1). In China, the country with the world's fastest growth, the bicycle conveys millions of workers to their factories every day.

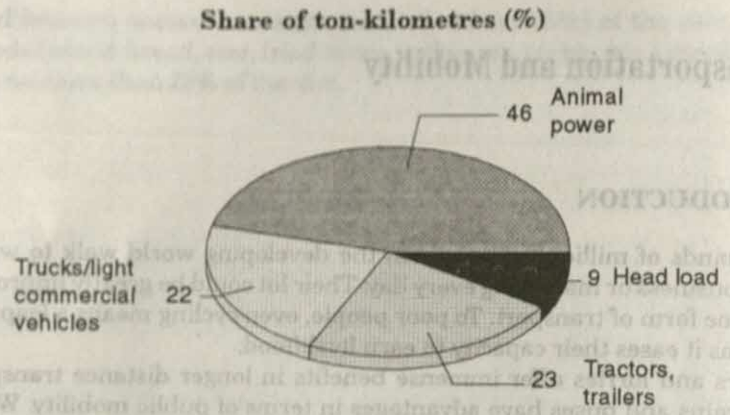

Fig. 5.1 Modal split in rural India (after National Council of Applied Economic Research, New Delhi, 1990).

A comprehensive approach to transport policy in developing countries is now needed. An integrated mobility strategy should (1) include all types of transport (e.g., walking, cycling, local public transport, motorized individual transport) in transport projects; (2) include the beneficiaries in the transport planning process (i.e., include pedestrians, cyclists, etc.), thus ensuring that people's needs and demands are taken into account; (3) consider not only transport infrastructures, but also the provision of the means of transport; (4) make cost/benefit calculations covering all the internal and external costs and benefits; (5) take account of both qualitative and quantitative criteria to properly assess transport projects; (6) tackle the transport issue cross-sectorally (e.g., agricultural project with transport components, unified energy, and finance policy); and (7) give due consideration to gender-specific aspects of mobility (Sieber and Kipke, 1998).

The majority of the world's urban population, over one billion people, lives in cities where air quality is far below WHO standards. Much of this pollution is generated by a small minority who own and operate motor cycles, trucks, private cars, and taxis although in some cases public buses can also be a major source. By the early 1980s, Beijing, Bangkok, Calcutta, New Delhi, Tehran, and several other cities were in violation of WHO air emission standards for over 200 days out of the year, and air emissions in most developing countries are projected to worsen dramatically in the coming decades. Road transport accounts for 70–85% of total airborne pollutants in most developing country cities. Airborne lead and carbon monoxide, both of which mostly come from road transportation, have caused learning disabilities in seven out of ten children in Mexico City. In 1990, about one-seventh of Bangkok residents suffered from chronic bronchitis and other respiratory diseases.

Private motor vehicle owners in developed countries are also responsible for the majority of greenhouse gas emissions. Over 70% of the motor vehicle-related carbon dioxide emissions come from the motorized minority in developed countries. Globally, transport accounts for 22% of total carbon dioxide emissions, some 66% of carbon monoxide, some 47% of nitrogen oxide, and 39% of hydrocarbons (Hook, 1998). More than 70% of these emissions come from the road sector. However, by the year 2025, over 50% is expected to be coming from the minority of motor vehicle operators in developing countries. While greenhouse gas emissions in other sectors are stabilizing, carbon dioxide emissions from the transport sector are projected to rise by 40–100% by the year 2025 (Hook, 1998).

In developing countries, where the majority suffer the effects of emissions generated by the affluent and rich minority, tightening and enforcing emission standards can go a long way in improving the health of the majority, while promoting the polluter pays principle (PPP).

In developing countries, the large majority of the perpetrators of road traffic accidents are operators of motorized vehicles and the majority of the victims are pedestrians and cyclists. Road traffic accidents are one of the three leading causes of death in developing countries, and 60% of the victims are generally moderate income pedestrians and cyclists. Over 600,000 people are killed every year in road traffic accidents, and another 50 million are seriously injured. In New Delhi, about 40% of the victims of fatal traffic accidents are pedestrians and about 15% tend to be cyclists. This compares with Bangkok's 47% pedestrians and 6% cyclists. In African cities also, most road traffic fatalities are suffered by pedestrians. In cities with high levels of motor cycle use, e.g., Kuala Lumpur and Bandung, motor cyclists usually represent the majority of the victims of road traffic accidents. In advanced countries, most of the victims of road traffic accidents are motor vehicle operators and passengers. In the light of the statistics given (Hook, 1998), it is strange that most traffic safety programmes focus on the safety of the motorized vehicle operator, rather than the vulnerable road users. This is exemplified by seat-belt laws, air bags, and better roadway markings for the safety of the operators of motor vehicles, rather than for the safety of vulnerable road users. Redesigning the front of the vehicle could greatly reduce the mortality rate of accidents, while building sidewalks and bicycle paths and removing dangers to cyclists such as open gratings could show dramatic safety improvements. But these areas have received little attention.

According to Hook (1998), pedestrians are the most efficient users of road space, followed by public transit vehicles of various types, followed by bicycles, and then private cars, etc. And yet in many cities of developing countries, most of the road space is consumed by a minority of the passengers.

Growing use of private motor vehicles is thus putting enormous constraints on the availability of road space in both developed and developing countries. Furthermore, the vast majority of cars carry only a single passenger (the driver).

Travel demand management or more efficient utilization of the existing road system such as increasing parking fees or requiring a second licence for entering congested downtown areas, traffic calming, high occupancy vehicle lanes and bus and bicycle lanes should help solve the growing traffic problem and its adverse consequences.

In many European cities, free bicycles have been provided for enabling people to undertake short-distance travel, shopping, etc., in downtown areas. Citizens from the suburbs leave their cars when they enter city limits, pick up a bicycle, do their work in the city, and then return to pick up their car, without paying anything for using the bicycle. The cost of the bicycles is borne by the city government from revenue earned from advertisers who advertise their products on the bicycles.

SUSTAINABLE TRANSPORTATION (INDIA)

The word transport (used as a noun) means carriage from one place to another. The concept of transport or transportation affects almost all aspects of daily life. The creation of transport facilities and capabilities is not an essential prerequisite for development but it can certainly facilitate it and act as a strong catalyst. Good transportation along with other infrastructural elements can greatly benefit economic growth.

India has close to a billion people whose activities spread over about 3.3 million square kilometres. Against this, its transport sector is not very large in size (see Table 5.1).

Table 5.1 Expenditure (in millions of rupees) on transport in some of India's five-year plans (after Ministry of Finance, 1996)

Sector	First plan 1951–56	Fifth plan 1974–79	Eighth plan 1992–97
Railways	2170	20,630	272,020
Roads	1470	17,010	128,330
Road transport		5030	41,190
Ports	280	4880	35,570
Shipping	190	4690	36,690
Inland water transport		160	3310

Certain activities in the transport sector are best undertaken only by the state. These include:

(1) Formulating policy matters and enacting the legal framework for undertaking economic activities by facilitating and allowing market forces to come into play.

(2) Ensuring appropriate safety regimes for different modes.

(3) Enabling proper and efficient functioning of regulatory authorities.

(4) Ensuring that user charges aim to meet full costs and at least cover marginal costs initially.

(5) Evolving sensible criteria for transport subsidies. For instance, providing the north-eastern states with an air service on a no-profit, cost-recovery basis, rather than through cross subsidies from trunk routes.

(6) Eliminating rent-seeking activities as directly unproductive rents can add significantly to costs for goods and services in several Asian countries.

(7) Giving due consideration to the idea that transport infrastructure development may be economically and socially justified but not commercially viable. For example, rural roads have high social but low financial returns. The state should provide resources for this activity but the building of the roads themselves should be a private sector activity contracted out with such funds. Further, transport services in rural areas are also better operated by the private sector (Raman and Anantharamaiah, 1998).

Today, the main mechanized surface transport modes in India are road and rail. Table 5.2 shows their relative market shares. Table 5.3 compares the increasing numbers of different types of vehicles from 1951 to 1991.

Table 5.2 Market share (%) of road and rail transport (after Anonymous, 1998)

Year	Freight		Passenger	
	Rail	Road	Rail	Road
1950–51	89	11	80	20
1996–97	40	60	20	80

Table 5.3 Number of registered motor vehicles in India (in thousands) (after Ministry of Finance, 1996)

Year (as on 31 March)	All vehicles	Two-wheelers	Cars, jeeps, taxis	Buses	Goods Vehicles	Others
1951	306	27	159	34	82	4
1971	1865	576	682	94	343	170
1991	21,310	14,047	3013	333	1411	2506

To facilitate sound development of the various modes of transport along good business norms and to encourage the use of efficient technologies, the policy framework should

(1) be neutral in permitting the choice of modes by users of transport,

(2) ensure the recovery of marginal costs from users,

(3) permit choices in technology on business considerations,

(4) minimize or completely avoid the role of pressure groups in business decisions in the sector, and

(5) encourage research in efficient technologies (Raman and Anantharamaiah, 1998).

Although the road transport industry in India has emerged as the dominant part of the transport system, it faces several difficulties in meeting emerging requirements. This is partly due to the inadequacies of the road network which, if expanded and upgraded, could help promote efficient vehicle operations. Part of the problem also lies in the inability of service organizations, especially in the public sector, to deliver services efficiently. With the industry having suffered from a near-absence of technological improvements in the design and manufacture of vehicles, there is urgent need to effect these changes immediately (Sriraman, 1998).

SUSTAINABLE URBAN TRANSPORTATION

A few countries have successfully developed direct solutions to the mobility needs of the majority without polluting the environment. General approaches include promoting increased public transit use, managing private motor vehicle traffic, increasing the affordability and attractiveness of bicycling, and facilitating intermodal approaches (Hook, 1998).

The world's best example of good traffic demand management is seen in Singapore which has designated its downtown a "Restricted Zone", requiring a special licence to enter during rush hours. The daily or monthly licences can be purchased at post offices. Fines for violations are very high. Monthly parking charges were also doubled on both public and private lots. Consequently, total vehicular traffic in the zone decreased by 50%, private car traffic decreased by 75%, and travel speeds downtown increased from around 18 km/hr to 30 km/hr (Hook, 1998). Singapore also developed a network of bike and pedestrian paths to the MRT (mass rapid transit) stations, and provided extensive bicycle parking facilities at the MRT stations. These measures generated a much higher economic rate of return, compared to the average 20% rate of return on most new road projects, and an estimated $500 million in cancelled road investments (Hook, 1998).

TRANSPORTATION AND (RURAL) POVERTY

For poverty alleviation, clear priorities need to be set on transport for the poor. The main contribution of the transport sector to poverty alleviation must include the improved access to goods and services. Roads alone do not automatically improve rural access, which is not only constrained by bad road conditions, but also by a low supply of means of transport and expensive transport services. Moreover, villagers perform most of their transport activities away from roads by walking on footpaths. Such walking can be trying and so restricts rural income and social development. Sensible transportation can have a strong impact on rural income because it improves access to places of employment and increases agricultural production by improved access to agricultural inputs, fields, storage facilities, and markets (Sieber, 1998).

Carrying goods accounts for a substantial fraction of the workload in several developing countries. Cheaper means of transport can significantly contribute to solving transport problems. Non-motorized transport plays a crucial role in this context.

Agriculture, selling crops, and buying essential household goods add to the transport workload. In some tribal areas of India, the nearest market may be several kilometres away, and people have to travel on foot to and from these markets; sometimes they carry heavy loads on their heads or backs.

There are two obvious but different solutions to the transport problem in developing countries. One is to bring essential subsistence supplies and economic infrastructure nearer the point of need and use. The second is to make transport both easier and faster. The first option is preferable but calls for a heavy investment beyond the capacity of most developing countries. Therefore, the second option perforce becomes a focus of concern, and it is here that non-motorized transportation becomes relevant.

Suitable changes in transportation can contribute to boosting of rural economy because transport costs make up a large proportion of the price of agricultural goods.

In developing a good road transport concept, the following distinction needs to be drawn. On the one hand, we have the local transport sector up to the level of farm-to-market roads; in this, the owner of transported goods and the owner of the means of transport are one and the same person. On the other hand, in the market-to-highway roads, there is a separation of route owners, vehicle owners, and goods owners. These routes are part of the official road network and belong to the state. They form the link to regional or national centres.

In Bangladesh, market turnover has, in some cases, increased many times as a result of improved accessibility to existing markets, and new markets have grown up at strategic points. The use of larger transport containers has cut traffic density significantly (see Opitz, 1998).

The transport impacts have also shifted production patterns. Farmers are increasingly growing and marketing cash crops. Reduced transport costs have resulted in cheaper input goods (fertilizer, etc.) and lower costs for delivering farm output. Without this change, these products would not be competitive. The sustainability of this level of activity greatly depends on the condition of the publicly-owned, market-to-highway roads whose maintenance in good condition is vital.

ECOLOGICAL DIMENSIONS OF SUSTAINABLE MOBILITY

If the concept of sustainability is carried forward to include mobility as well, then sustainable mobility must also embrace the ecological, economic, and social dimensions. The indicators for the ecological sustainability of transport can include fuel consumption (strictly speaking, sustainability would have to mean zero consumption of non-renewable resources), exhaust emissions, greenhouse gases, noise, and depletion of natural land (Opitz, 1998). As regards economic sustainability of transport, efficiency needs to be considered in terms of the economy as a whole (self-financing of all internal and external costs) and traffic safety. Some criteria for social sustainability include traffic safety and appropriate access to mobility for all.

The relevance of sustainable mobility to rural transport in developing countries is not so much an issue of the traffic avoidance or traffic displacement approaches prevailing in the industrialized countries in response to depletion of the environment, but entails the kind of transport system geared to progress in agricultural production and the provision of public benefits while being capable of financing itself, including all its external costs (Opitz, 1998).

FOSSIL FUELS AND TRANSPORTATION

The growing dependence on fossil fuels, congestion of carriageways or air routes, and the propensity of the transport sector to ruin the environment call for strict and stringent regulatory constraints. In developed countries, most people like to have personalized transport but there is some shift toward public transport as this is the only way to effectively deal with energy, congestion, and environmental concerns. Public transport can carry larger number of people over longer distances using less road space and fuel per person and at the same time cause less pollution. Priority to public transport can be achieved to an extent by traffic limitation strategies and pricing but, considering the rapid deterioration in the quality of life especially in the urban areas, stringent regulatory measures will be required in the future. The regulatory aspects may be outlined as follows:

(1) *Goals of regulation.* Protection of public interest; transport as a viable business to attract better manufacturers and operators; supporting national and strategic interests.

(2) *Economic regulation.* Fare and entry regulation; quality-of-service regulation; tax regulation.

(3) *Physical and infrastructure regulation.* Quality of roads and carriageways; quality of vehicles and carriers; maintenance efficiency.

(4) *Social policy regulation.* Balanced regional development; equity; energy and environmental issues; consumer protection (Padam, 1998).

TRANSPORTATION AND ENVIRONMENT

Transport, especially road transport, has a strong environmental impact, and a variety of measures can be taken to reduce environmental damage by road transport. No doubt, transport is essential for economic and human development.

The environmental effects of transport differ by mode. Non-motorized transport generally does not harm the environment.

The environmental effect of rail transport comes from the use of coal (for generating electricity) and the use of diesel oil in diesel locomotives.

Inland waterway transport is fuel-efficient and has relatively little environmental impact. In oceans, major damage occurs from tanker accidents. Shipping can pollute coastal waters.

Aviation causes local air and noise pollution at ground level, and gaseous emissions that can deplete the ozone layer.

The transport sector consumes a large part of the petroleum used in many countries. Air pollution caused by emissions from motorized vehicles is a serious environmental issue. The main emissions from motorized road vehicles equipped with spark ignition gasoline engines include carbon monoxide (CO), oxides of nitrogen, unburned hydrocarbon in the exhaust, suspended particulate matter (SPM), and lead aerosols, and certain other hydrocarbon emissions.

The most significant emissions from diesel-run vehicles include SPM, oxides of nitrogen, sulphur dioxide, carbon monoxide, and hydrocarbons.

Both diesel- and gasoline-fuelled vehicles, particularly the two-stroke gasoline engines, used in two-wheelers and three-wheelers, emit CO_2. Hydrocarbon emissions from these vehicles are quite high because a significant part of the air-fuel mixture escapes unburnt into the exhaust, so about 20–25% of the fuel used is lost in this way. Particulate emissions from two-stroke engines are also high (Faiz *et al.*, 1996). Hydrocarbon emissions from one two-stroke motor cycle may exceed those from three uncontrolled passenger cars, and particulate emissions can exceed those from a heavy duty diesel truck. This is a cause for serious concern in India where two-wheelers and three-wheelers now constitute nearly 80% of the registered vehicles; many of these use two-stroke engines, and account for 45% of total gasoline consumption (Nanjundaiah, 1998). Air pollution in urban areas is associated with higher incidence of respiratory ailments such as bronchitis and asthma, especially in children (see Kumar, 1995).

Recent technological advances have made it possible to reduce air pollution caused by vehicles. These advances relate to vehicular technology improvements, fuel options for controlling emissions, and alternative technologies. For gasoline-fuelled automobiles, technology improvements involve engine modifications, use of three-way catalysts and electronic engine control systems, and lean burn techniques combined with oxidation catalytic converters that help reduce pollutants as well as fuel consumption.

For diesel-powered vehicles, emissions can be greatly reduced through engine design changes, improved fuel injection systems, turbocharging, and charge air-cooling. These changes also improve fuel economy significantly but increase engine costs. Use of low-sulphur fuel and an oxidation catalytic converter can reduce particulate matter and hydrocarbon emissions (Nanjundaiah, 1998).

For two-stroke gasoline engines in two- or three-wheelers, emissions are reduced by adopting advanced two-stroke design incorporating timed fuel injection and crankcase lubrication or switching to a four-stroke design. This can reduce hydrocarbon and particulate emissions by about 90% and fuel consumption by about 30%. Catalytic converters are being used in two-stroke motor cycles in Taiwan and in mopeds in Switzerland.

Pollutant emissions can be reduced by up to 30% through cost-effective fuel modification, e.g., removing lead from gasoline. Lead-free gasoline is now also gaining popularity in big cities in India.

Conventional diesel fuel may be improved by reducing its contents of sulphur and aromatics and by using detergent additives.

Gasoline and diesel can be substituted by cleaner burning fuels such as compressed natural gas, liquefied petroleum gas, methanol, ethanol, gasohol, and biodiesel.

Hydrogen gas which can be generated by illuminating algae with sunlight is a clean burning fuel. Work is underway on hydrogen-powered vehicles in Canada, Germany, and the USA. A prototype 60-passenger bus is already being run in Vancouver, Canada (Nanjundaiah, 1998).

Fuel cell technology converts chemical energy to electricity and has potential application in cars. Electric cars have been made that are less complex than gasoline vehicles, produce no emissions, and are clean. The limitations of these cars include the smaller running range and repeated battery-charging requirements.

Hybrid vehicles (an electric vehicle that uses two or more power sources, one of which being a battery pack) have been developed, but are expensive.

ECOTOURISM

Ecotourism can be defined as travel that conserves the natural environment and sustains the well-being of local people. For many countries in the developing world, unspoilt nature is an asset that can be turned into quick profits. But the danger is that tourism could destroy the pristine nature and culture that attract visitors in the first place. Ecotourism can be a key to saving threatened natural habitats while developing poorer regions.

Environment-friendly travel with a nature dimension is enriching for the tourist. The concept of ecotourism is also supposed to imply benefits for local people and conservation. But in some cases, it can be more harmful than beneficial. Environmentally-sound tourism may be defined in different ways:

(1) *Sustainable tourism*, in the spirit of the 1992 Earth Summit in Rio de Janeiro, covers all forms and destinations, mass tourism and small-scale travel, and cities and rural areas. A small proportion of the industry as a whole consists of nature-based tourism which also includes ecotourism.

(2) *Nature tourism* simply means that people visit areas of natural interest and beauty; this can be done in the form of pleasure trips which are not ecologically sustainable. Vehicle safaris in Africa are a case in point: though inspired by the tourists' interest in nature, they cause erosion, disturb wildlife, and leave behind a trail of rubbish.

(3) *Ecotourism* is a narrower concept, implying more pronounced benefits for nature conservation and local development.

Ecotourists travel in small groups to areas of natural and cultural interest, preferably taking care to leave no trace of having been there. Visits should be planned in such a way that local people become aware of the economic benefits of protecting natural resources and see this as a long-term goal.

Nature-based tourism as a whole currently accounts for only about 7% of all tourism, and ecotourism for a much smaller proportion.

One basic idea in the ecotourism concept is less foreign involvement and a greater emphasis on local development and marketing of holidays.

One good approach may be locally-owned hotels, built by local labour with local materials, in which tourists are served locally-produced food and drink and provided with well-trained local guides.

Tourism can be sustainable if it

(1) operates within natural capacities for the regeneration and future productivity of natural resources;

(2) recognizes the contribution that people and communities, customs and lifestyles make to the tourism experience;

(3) accepts that the people must have an equitable share in its economic benefits; and

(4) is guided by the wishes of local people and communities in the host area.

The seven cardinal principles for sustainable tourism are

(1) use resources sustainably,
(2) reduce overconsumption and waste,
(3) maintain diversity,
(4) integrate tourism into planning,
(5) support local economies,
(6) involve local communities, and
(7) market tourism responsibly.

6

Resource Management

INTRODUCTION

There are different types of traditional resource management systems that are important in the context of different settings of cultural identification with the environment and of explicit regulations regarding resource use. Local environmental knowledge has often been developed and refined for the success of such customary systems. Social mechanisms which maintain sustainable levels of resource use within a given society are often not readily perceptible to outsiders. Several factors affect the sustainability of common property regimes.

Many traditional resource management systems, by adapting and remaining viable in the face of pressures from within and without the system, have stood the test of time and survived. It is widely believed that population pressure exerts a profound impact on traditionally-sustainable resource use. In many situations, the conventional conception of a direct relationship between population growth and increased pressure on the environment holds good; however, such a relationship is by no means inevitable. There are examples of cases in which population decline has resulted in environmental degradation, and of other cases in which growing populations have been able to adapt their methods of resource management in a sustainable manner (Vivian, 1991).

Various kinds of collective action can be undertaken by communities whose livelihood is threatened because they have been deprived of their traditional means of resource management, or because of unsustainable resource exploitation on the part of outsiders. The ecological knowledge of societies which are based on sustainable environmental management practices equips them to better judge the real effects of ecosystem disturbance than outside evaluators. However, the success of local attempts to intervene in the implementation of policies or projects which adversely affect the environment depends on a variety of factors, including the ability of local organizers to form coalitions with regional, national or international groups with similar interests, and the existence of social, economic, and political structures which allow the formation of such alliances, and the expression of their concerns (Vivian, 1991).

Some of the action taken by development practitioners to address local-level environmental problems in the Third World consists of such programmes as tree planting schemes, soil *bunding* (raising a low boundary wall around the field for water retention) efforts, and improved irrigation management strategies, which seek to establish sustainable resource use for selected target areas. Current discussions of environment and development issues often mention people's participation as a prerequisite for sustainable development.

Evidence is mounting that the targeted project approaches to environmental problems, though often well-intentioned may not suffice to solve the environmental problems facing the South today. The problems are so serious and extensive that they cannot be tackled with the localized adhoc, palliative remedies presently offered.

Rural folk of the Third World need to be taught about the importance of environmental conservation. The lack of awareness of the benefits of conservation and of its relevance to everyday concerns is an important problem to be overcome before sustainable development can be attained.

There is a strong need for giving increased recognition to traditional resource management practices, an analysis of the value of such practices under current and future conditions, and an assessment of ways either to ensure that sustainable practices are maintained, or to adapt the most viable of them for use in different economic, social or environmental contexts. Also, the concerns, goals, and activities of local grass roots organizations and social movements should be incorporated into externally-assisted projects in such a way that the latter can become self-sustaining and self-replicating without additional external inputs.

SUSTAINABLE DEVELOPMENT

Sustainable development is usually defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It implies some improvement in living levels of the poor people. In the Third World, improved living levels depend largely on increased consumption of resources. Therefore, this definition of sustainable development means that present levels and methods of resource exploitation should not degrade the environment to such an extent that resource availability in the future will decline. However, living levels also depend on other environmental factors that are unrelated to economic or physical resource yields, including the availability of clean air and adequate living space and, in many circumstances, people's ability to maintain a spiritual, cultural or aesthetic relationship with their environment. The foregoing definition, therefore, also suggests that ecosystem conservation plays an important part in sustainable development.

TRADITIONAL RESOURCE MANAGEMENT SYSTEMS

Rural folk who rely heavily on natural resources for their livelihood have always developed methods to ensure the conservation of their environment. These methods tend to be more explicit and transparent in situations where resources are very scarce, such as in arid lands.

There are numerous descriptions, for instance, of religious or spiritual significance being attached to certain plants or animals, which are thereby protected. In India, the religious beliefs of the Bishnoi community in Rajasthan have prohibited the killing of animals or the cutting of green trees since the fifteenth century. Consequently, Bishnoi land continues to be a green and flourishing area in the midst of the surrounding Rajasthan desert (Sankhala and Jackson, 1985). Also common are customs prohibiting the exploitation of particularly useful species (e.g., the pipal tree in Asia) or allowing the harvesting of animals or plants only at certain seasons or otherwise under conditions which minimize damage to their reproductive potential.

TRADITIONAL SYSTEMS AND POPULAR INITIATIVES

Reaction against infrastructure projects, such as dams and roads, which threaten destruction of the environment is a common form of environmental resistance movements. The larger projects such as the Narmada dam in India have attracted the greatest attention, but these are by no means the only examples. Environmental activism does not occur only when complete environmental destruction is threatened, but can also result from conversion of resources from one form to another in a way which adversely changes traditional ways of life. Environmental activism in the Third World involves not only struggle against the expropriation of resources, but also resistance to resource overexploitation by outsiders. Forest communities have been threatened by logging in several countries such as Malaysia, India, Thailand, the Philippines, and Brazil.

Collective action to resist the implementation of environmentally-damaging projects is rarely activated primarily by any strong concern for preservation of the environment but rather comes from the lack of sufficient benefits from such projects accruing to local communities.

In view of their extensive ecological knowledge, societies based on sustainable environmental management practices are better able to accurately assess the true costs and benefits of ecosystem disturbance than any outside evaluator. However, it is also emerging that environmental activism does not flourish *in vacuo*. The impact of such movements depends largely on the social, economic, and political structures which affect community dynamics.

It is commonly believed that poor people are forced to cultivate marginal lands because they will not otherwise be able to survive the present season. As a basis for understanding the primary causes of environmental degradation, this model is not particularly helpful. It may be equally true that the excessive wealth and overconsumption of industrialized societies is responsible for most of the unsustainable resource extraction, and that wealth may therefore be more appropriately blamed for ecological problems than poverty.

GLOBAL WATER RESOURCES

Lack of water severely constrains everything from food production to economic development and protection of natural ecosystems. It is high time that we disciplined ourselves in conserving and recycling water for if we fail to do so, we will surely end up living in a Sahara-like desert.

Water is undoubtedly humankind's most important resource in life. No matter how rich a person is, without water he or she cannot live because water is both the least expensive and most essential commodity used by humans.

Water scarcity is now becoming a global problem but is particularly serious in many developing countries. This is seen daily when people queue up for a pail of water either for drinking, watering, cleaning or washing purposes. Potable water has become a scarce resource. Some notable sources of water are shallow wells, impounded rainwater, lakes, and springs; all these are susceptible to pollution and contamination (Cummings, 1990).

Fifteen countries in North and West Africa, and in West Asia are already affected by acute water shortage. Millions of people do not have access to hygienically safe water. Access to safe water and adequate sanitation could result in two million fewer deaths among young children.

Water is not only useful but could be hazardous to human life and property. Typhoons, intense rainfall, overflowing of waterways, inundations and deposition of sediment in the flood plains, pollution and contamination, and extensive flood damages can cause havoc.

The hydrologic cycle (Fig. 6.1) has a central importance in ecosystems. The water molecule is inherently connected to all living things and is a mover of many abiotic components of ecosystems (see Kumar and Häder, 1999). This importance arises from two properties of water. Firstly, water is needed by all organisms during at least part of their life cycle. One well-known axiom of biology is that "the fires of life burn only in water"; in other words, metabolism can occur only in an aqueous medium. Secondly, water is the great transporter of everything from blood and sap to nutrients, fish, and energy. So, water unites the world, circulating through it in a continuous cycle and carrying life's most basic needs—food, nutrients, and energy (Noss and Cooperrider, 1994).

The major stores in the hydrological cycle are shown in Fig. 6.2. Figure 6.3 shows the mean annual flux rates within the global hydrological cycle.

The essential interrelatedness of entire river systems is apparent from the frequent observation that biotic communities along a stream are interconnected and also that they maximize the capture and use of energy and nutrients. What is less appreciated is the interrelatedness of the terrestrial, wetland, and aquatic worlds. The central importance of the riparian zone as the link between the terrestrial and aquatic systems cannot be overemphasized. Aquatic systems do not occur in isolation but are parts of the landscape.

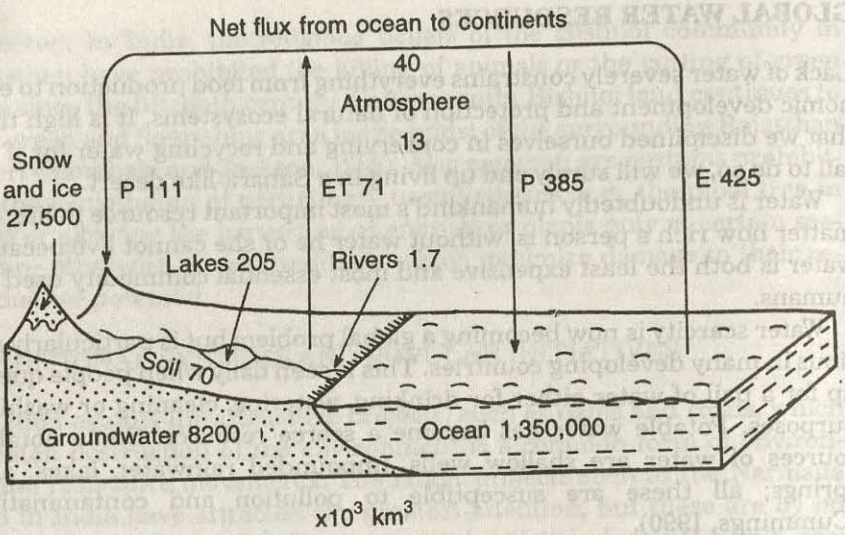

Fig. 6.1 Global hydrological cycle (P, precipitation; ET, evapotranspiration; E, evaporation) (after Jones, 1997).

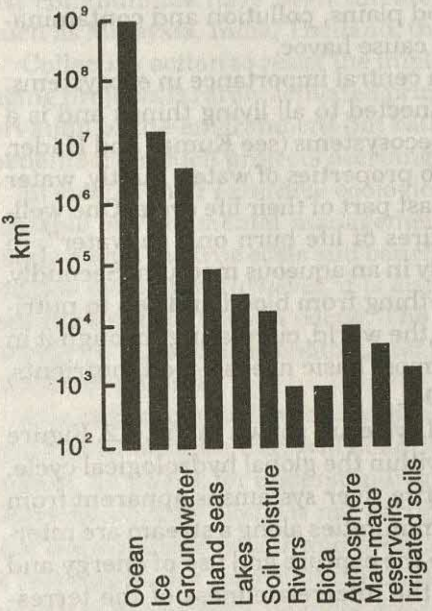

Fig. 6.2 Major stores in hydrological cycle (after Jones, 1997).

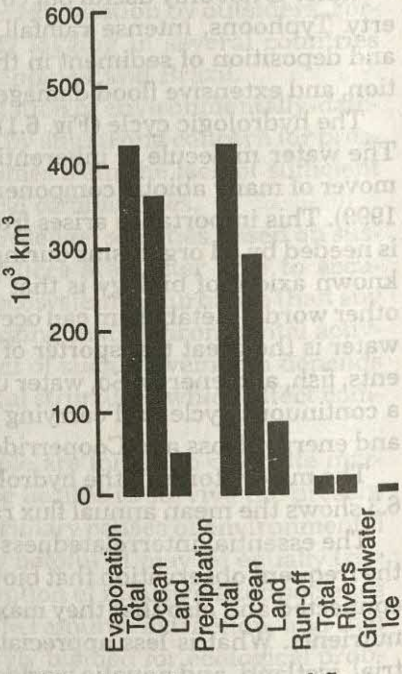

Fig. 6.3 Mean annual flux rates (approximate) within global hydrological cycle (after Jones, 1997).

The hydrologic cycle of evaporation, precipitation, and infiltration/run-off best illustrates the principle that everything must go somewhere. Freshwater is a great determinant of the density of life (biomass) in terrestrial systems and is more usable by most life-forms than is salt water. Yet freshwater happens to be a very small percentage of the global water and its turnover is rapid compared with other sources (Table 6.1). Keeping freshwater within the terrestrial portion of its cycle is crucial to maintaining the overall biomass and diversity of life in terrestrial systems.

Table 6.1 World water resources and rate of renewal

Location	Percentage of world supply	Average rate of renewal
Oceans	97.134	3100–37,000 yr
Atmosphere	0.001	9–12 days
On land		
Ice-caps	2.225	16,000 yr
Glaciers	0.015	16,000 yr
Saline lakes	0.007	10–100 yr
Freshwater lakes	0.009	10–100 yr
Rivers	0.0001	12–20 days
In land		
Soil moisture	0.003	280 days
Groundwater to a depth of		
1000 m	0.303	300 yr
1000–2000 m	0.303	4600 yr

Water flowing downhill carries several substances along with it, e.g., nutrients, silt, pollutants, and many other living and non-living components of the ecosystem. It takes nutrients downstream, these nutrients being captured by plants and animals. Indeed, all land represents a downhill rolling motion of nutrients from the hills to the sea. Plants and animals absorb nutrients out of the soil and air and pump them upward through the food chains. Death spills them back into the soil and air. Mineral nutrients, between their successive trips through this circuit, are washed downhill. Lakes and soils retard this downhill wash. Without the impounding action of soils and lakes, plants and animals would have to follow their salts to the coastlines.

Both terrestrial and aquatic systems have developed elegant mechanisms to slow down and retain water, nutrients, and energy in its flow back to the sea. Forests and trees intercept moisture, thus reducing the energy of impact on the ground and increasing infiltration into the soil, and reducing run-off.

Herbaceous vegetation and litter in rangelands facilitate increased infiltration and decreased run-off, but most rangeland soils are less capable of absorbing rain. Even though precipitation in rangelands is typically much less than in forests, there is often more run-off and thus greater sedimentation of streams. Possibly, rangelands contribute more to sedimentation than do forestlands.

Riparian and wetland vegetation also help trap and hold sediment and nutrients and keep them in the system. This process is closely related to the way in which riparian systems reduce or buffer the energy of high flows. Riparian and wetland vegetation slows down the flow of water, allowing sediment and organic matter to settle out and be deposited. At the same time, alluvial riparian zones tend to behave as shallow aquifers that recharge at high flows and drain at low flows, thereby retarding water movement on its downhill journey.

Estuaries are the final depositories for most silt, organic matter, and nutrients. They have high animal species richness and among the highest animal biomass of any habitat on earth. As with upstream riparian/wetland areas, estuaries enable birds, fish, and other animals to capture nutrients and move them back upstream or onto land.

Animals are a primary means for returning scarce nutrients to terrestrial systems. Salmon and some other fishes are the chief vehicles for transfer and release of biomass and minerals upstream and so also are mayflies and other emergent aquatic insects in moving energy and nutrients upstream. Thus, riverine systems provide corridors for movement of energy and nutrients upstream as well as downstream.

THREATS TO AQUATIC BIODIVERSITY

Three types of human threats to aquatic biodiversity are (1) resource misuse, (2) pollution, and (3) exotic species. Resource misuse ranges from building dams to livestock grazing.

Some impacts of damming and diverting waters include loss of stream habitat, blockage of fish runs, and loss of downstream nutrients. Long-term effects are, however, not known. Dams destroy riverine habitat and obstruct movement of aquatic organisms (Table 6.2), severely affecting biodiversity both directly and immediately, and also more subtly due to long-term secondary, tertiary, or cumulative effects.

Diversion of water creates some problems in the system from which it is diverted, and also causes damage in its new path in course of time. Diversion of water for irrigation can lead to salinization and waterlogging of soils. Because most existing farmlands have already been converted from their natural vegetation, their value for conserving biodiversity today is quite low. As their fertility can be destroyed by waterlogging and salinization, the demand for fresh fertile lands will put additional pressure on remaining natural areas. Also, salinity problems are not confined to farmlands. Salinity problems can be partly relieved by flushing the accumulated salts out of the soils.

Figure 6.4 illustrates the global trend in water pollution.

Table 6.2 Impacts of dams and diversions on biodiversity (after Noss and Cooperrider, 1994)

Dam activity	Primary effect	Secondary and tertiary effects
Flooding of backwaters	Destruction of riverine and riparian habitat; creation of barrier for movement along and across riverine and riparian corridor	Loss of species, loss of riverine and riparian connectivity; depressed species populations; extirpation; extinction
River obstruction	Interception of downstream flow of nutrients and silt	Decreased nutrient supply to downstream habitats; biotic impoverishment of downstream communities
	Blocking of upstream movement of migratory fishes	Lowered population abundance; genetic deterioration; extirpation; extinction
Regulation of water flow	Decrease in peak flows (flood control; hydroelectric dams)	Decrease in natural disturbance cycles and in flushing flows; degradation of downstream habitat; biotic impoverishment of downstream communities
	Irregular flow (hydro-electric power)	Abnormal fluctuation in downstream habitat; depressed populations; extirpation; extinction
	Decrease in winter flows (irrigation)	Decrease in available habitat in winter; depressed populations; extirpation; extinction
	Warming of water	Degradation of downstream aquatic habitat; depressed populations; extirpation; extinction
Water diversion	Decrease in downstream water flows	Decrease in available habitat downstream; depressed populations; extirpation; extinction
	Diversion of water to farmlands	Loss of wild lands to agriculture; decreased available habitat; depressed populations
	Water to river with increased salinity	Increased salinization of degraded habitat; depressed populations

PROTECTION OF WATER RESOURCES

It is impossible to achieve sustainable development unless the world's water resources are carefully preserved. In this context, the following features are noteworthy:

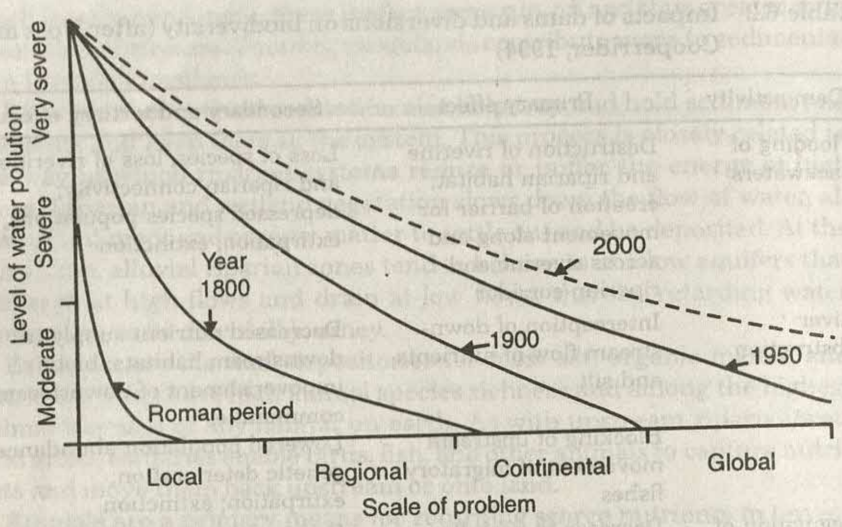

Fig. 6.4 Global trend in water pollution (after Jones, 1997).

(1) Less than 1 part in 100,000 of the earth's water is available for human use.

(2) Polluted water affects the health of some 1.2 billion people and contributes to the death of some 1.5 million children under 5 years every year.

(3) The availability and quality of freshwater are closely linked to environmental changes, especially urbanization and deforestation.

Freshwater resources are likely to be further depleted by the rapid growth of population, especially in developing countries. Any plan for sustainable development should ensure that current decisions on water resources do not jeopardize the interests of future generations. This implies not only preserving the present resources of freshwater, but also careful planning to avoid future stress. Two methods are used to evaluate development alternatives. They are based on matrices or simulation models. Matrix methods are designed to consider all possible interactions and impacts and then decide on their relative importance in terms of specified criteria (WMO, 1993). Simulation models are also used to assess the impact of a specified plan for water management. Certain conflicts of interest also arise in hydrology between sustainability and development. The following facts are relevant in this context:

(1) About 80% of the world's arable land is rain-fed. Its productivity can be increased by better retention of soil moisture and the use of drought-resistant varieties of crops. Fish production in individual catchments is also useful.

(2) The potential for irrigation should be fully utilized by avoiding misuse of land.

(3) Water resources for irrigation come mainly from surface water resources. Water reservoirs and tube wells are used. These sources should not be degraded by salinization. Wastage of irrigation water should be minimized. In many areas, more water than is necessary is used for growing a crop. In rain-fed agriculture, steps should be taken to prevent waterlogging and excessive salinity by proper drainage.

RIVER RESOURCES

Anthropogenic activities such as overgrazing, poor lumbering practices, and water diversion have seriously degraded riparian ecosystems around the world.

The loss and degradation of the streams and riparian ecosystems in some countries have already reached crisis proportions. At least three-fourths of existing riparian areas in the USA have been extensively altered and more than half of the American wetlands have been lost. In the USA as well as several other countries, including India, hydrologic disturbances from water diversions and dams; non-point sources of pollution and sediments from agricultural, forestry, and urban land practices; and vegetation removed by logging and cattle grazing all have damaged riparian ecosystems and have impaired their capacity to support fisheries and wildlife, purify water, and check flooding. Over 75% of historical Pacific Northwest salmon stocks are either extinct, endangered or threatened. Restoration may help repair the damage, but little is known about how to use the tools of restoration effectively, especially to improve the ecological condition of a watershed or region (Kaufmann *et al.*, 1997; Olson and Harris, 1997; Kentula, 1997). A good appreciation of the larger landscape and system to be restored is integral to proper siting of restoration projects.

Goodwin *et al.* (1997) suggested that riparian ecosystems consist of two zones: Zone I occupies the active flood plain and is frequently inundated, and Zone II extends from the active flood plain to the valley wall. Successful restoration depends on an understanding of the various processes that influence natural riparian ecosystems and the types of disturbance that degrade riparian areas. Goodwin *et al.* recommended adopting a process-based approach for riparian restoration. Some causes of disturbance emanate from streamflow modification of the riparian ecosystem, and watershed disturbances. The four aspects that need to be addressed to advance the state of science for restoration of riparian ecosystem are (1) interdisciplinary approaches, (2) a unified framework, (3) a better understanding of the fundamental riparian ecosystem processes, and (4) restoration potential related more closely to the disturbance type. Three issues should be considered regarding the degraded environment, namely, (1) location of the causative disturbance with respect to the degraded riparian area, (2) whether the disturbance is ongoing or can be eliminated, and (3) whether or not recovery will occur naturally if and when the disturbance is removed (Goodwin *et al.*, 1997).

No single definition can be applied to all riparian ecosystems. Most definitions differ in the specific criteria used to define both the boundary between riparian and upland ecosystems and the different zones that may exist within riparian ecosystems. Broadly, riparian ecosystems are the narrow ecotones between aquatic and terrestrial ecosystems that consist of several fluvial surfaces, including channel islands and bars, channel banks, flood plains, and lower terraces (Fig. 6.5). This definition includes those areas directly influenced by frequent flooding (Zone I) and areas adjacent to a river that resulted from past fluvial action, but which are generally not currently influenced by fluvial processes (Zone II). Zone I areas are subject to current-day fluvial geomorphic processes, and are at elevations that allow shallow-rooted plants to extract water from the water-table. Zone II represents areas that were formed by past fluvial geomorphic processes and are higher in elevation than surfaces in Zone I, and in which vegetation is dominated by deep-rooted plants capable of extracting water from the underlying alluvial aquifer. Whereas Zone I occurs on moist, lower, more frequently flooded surfaces, Zone II occurs on inactive flood plains and higher terrace surfaces, is drier and less subject to flooding. The separation between two zones is not always distinct. Nevertheless, dividing riparian ecosystems into these two zones helps differentiate among the structural and functional properties of the varied surfaces.

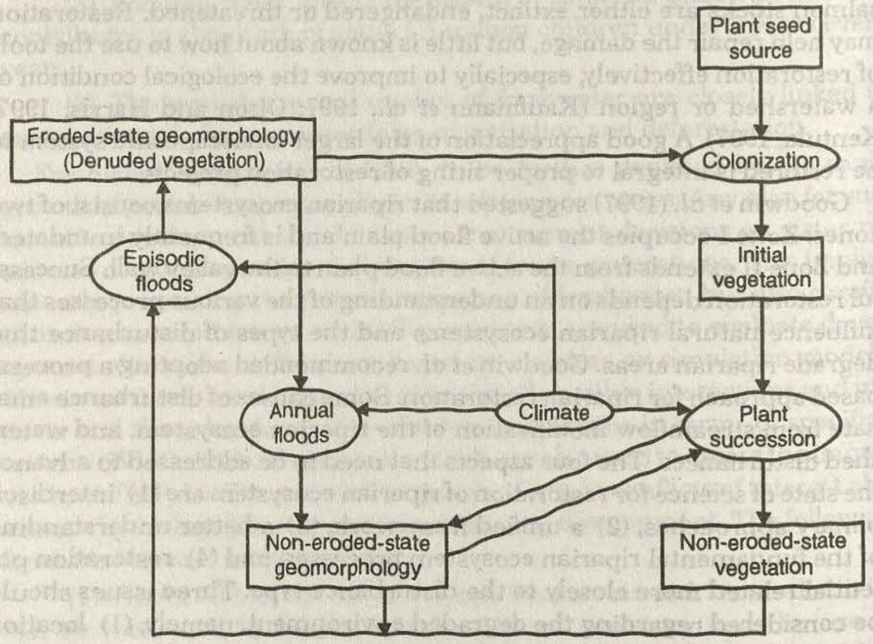
Plant seed source
Eroded-state geomorphology (Denuded vegetation)
Colonization
Episodic floods
Initial vegetation
Annual floods
Climate
Plant succession
Non-eroded-state geomorphology
Non-eroded-state vegetation

Fig. 6.5 Fluvial and ecological processes that interact to form riparian landscapes. Arrows represent causal pathways through which geomorphic conditions or vegetation (boxes) is changed by physical or biological processes (ovals). (After Goodwin *et al.*, 1997.)

Areas in Zone I are intimately linked to stream ecosystems, and the two ecosystems exchange energy and matter. The exchange of energy and matter in Zone II is largely unidirectional, with Zone II providing material and affecting energy inputs to both Zone I and the stream ecosystem.

Two principal processes are involved in the creation of riparian ecosystems. Both depend on regional climatic conditions: hydrogeomorphic processes and biotic change (Fig. 6.5).

One interesting aspect of riparian ecosystem restoration is that it usually cannot be divorced from stream restoration, though the opposite has not always been true. Many streams have been restored specifically to enhance fisheries by re-establishing aquatic habitat, without explicitly mentioning the riparian ecosystem (Newbury, 1995).

The greatest limitation in riparian ecosystem restoration is the lack of understanding of the underlying physical and ecological processes of the riparian zone and the interactions and feedback among these processes (Gregory *et al.*, 1991).

But there has been some progress in developing physically-based understandings of riparian zone processes and functional relationships (see Nanson and Croke, 1992; O'Neill *et al.*, 1997; Hupp, 1992).

WATER QUALITY MANAGEMENT

Unless means are found to prevent the continued water quality deterioration, the freshwater quality problem has the potential to become a threat to human survival. Water, in its many forms, is used—and abused—in diverse sectors of human society. The role water plays as the bloodstream of the biosphere accounts for the biological damage and reduced biodiversity inflicted by water pollution.

Pollutants discharged into the water cycle derive from three main sources: human and livestock waste (mainly biodegradable organic products), discarded industrial products and industrial waste (often toxic and accumulating readily in food chains), and agricultural chemicals (fertilizers and pesticides) used to obtain high yields needed to feed rapidly-expanding human populations (Falkenmark, 1993).

In the developed countries, the problem of human biological waste is solved by waste water treatment; industrial waste is increasingly being limited by strict quality constraints to minimize the harmful substances entering water systems. Agricultural pollution, on the other hand, has not been effectively solved. In the South, the rapidly-increasing volume of waste being produced by the expanding urban areas, industry, and agriculture is a major challenge. Serious difficulties arise wherever growing population density is increasing the demand on finite water resources.

Some radical methods of solving the worldwide problem of water pollution are: (1) enlightenment at all levels of society to ensure necessary changes in attitude; it is especially important that the call for action, sounded by water experts, is heeded by economists and politicians;

(2) transforming a fallible, sectorized administration into an administration responsible for ensuring not only multisectoral integration, but also integration of land use and water management; (3) replacing obsolete legislation by effective and enforceable laws necessary to bring about a change in attitude; and (4) adequate monitoring of water quality so as to provide the necessary data on which to base political decisions (Falkenmark, 1993).

INTEGRATED COASTAL MANAGEMENT

Interference in nature and the living habits of man should be viewed holistically, including social and economic interactions (Figs. 6.6, 6.7), with the network of dependencies, of cause and effect, requiring interregional and intersectional consideration. Regional planning of spatial utilization—standard practice for every good development programme in agriculture—is not applicable to coastal regions where the problems and the multidimensionality of space, the elements, and social dependencies in the rural or urban settlement areas are far too complex. This is the region that man exploits most intensively and yet its planned management has only occurred in exceptional cases (Scura *et al.*, 1992).

Coastal regions are bounded by the sea on the one side, and on the other side there is a transition from the utilization of predominantly aquatic resources (wetlands and lagoon systems) to livestock and arable farming. The width of the coastal strip varies but is generally about 60 km.

Every sixth inhabitant of the world resides within this 60-km-wide coastal strip. In 2–3 decades, this figure is likely to double. Indeed, in the next few decades, increasing population pressure is sure to press towards the coastal regions and into periurban centres (Lohmeyer, 1998).

Past experiences in multi- and bilateral management cooperation have shown that the living conditions of fishermen cannot be improved by way of monosectoral development approaches, but an integrated regional development approach may solve some of the problems.

Even if it remains restricted to the relatively narrow coastal strip, a successful application of integrated coastal management (ICM) requires the establishment of a common work platform for all its players (Fig. 6.7).

The core zone is the living area of the coastal inhabitants. In coastal villages, they are mostly fishermen, small traders, farmers, hunters, and gatherers. They benefit from ICM in many different ways (Clark, 1992), e.g., through sustainable growth on the basis of the utilization of natural resources; protection of the natural habitats and the variety of species; control of the entry of harmful substances and changes to coastal land and beaches; control of water inflow (deposits of sediments and harmful substances); checking the removal of corals and changes to lagoons and the seabed; rehabilitation of damaged areas; and provision of technologies and rational allocation of resources.

The two essential prevailing conditions indispensable for optimal utili-

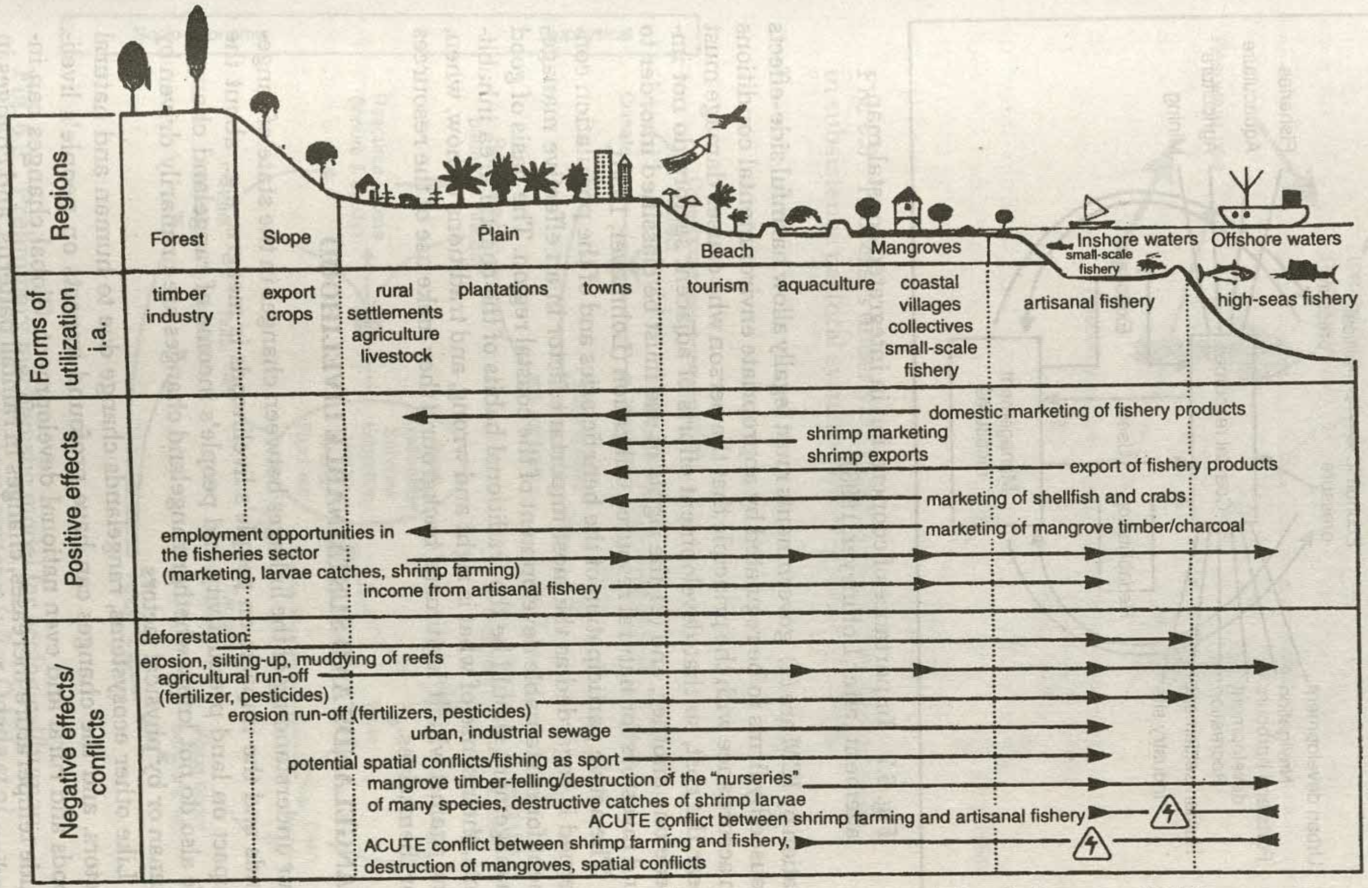
Regions
Forest
Slope
Plain
Beach
Mangroves
Inshore waters
small-scale fishery
Offshore waters
Forms of utilization i.a.
timber industry
export crops
rural settlements agriculture livestock
plantations
towns
tourism
aquaculture
coastal villages collectives small-scale fishery
artisanal fishery
high-seas fishery
Positive effects
domestic marketing of fishery products
shrimp marketing
shrimp exports
export of fishery products
marketing of shellfish and crabs
marketing of mangrove timber/charcoal
employment opportunities in the fisheries sector (marketing, larvae catches, shrimp farming)
income from artisanal fishery
Negative effects/ conflicts
deforestation
erosion, silting-up, muddying of reefs
agricultural run-off (fertilizer, pesticides)
erosion run-off (fertilizers, pesticides)
urban, industrial sewage
potential spatial conflicts/fishing as sport
mangrove timber-felling/destruction of the "nurseries" of many species, destructive catches of shrimp larvae
ACUTE conflict between shrimp farming and artisanal fishery
ACUTE conflict between shrimp farming and fishery, destruction of mangroves, spatial conflicts

Fig. 6.6 Relations between coastal fishery and other sectors (after Lohmeyer, 1998).

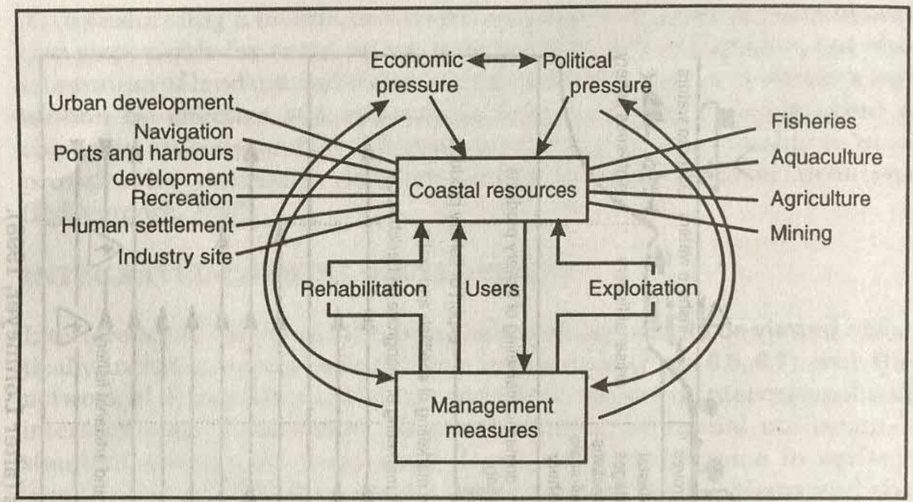

Fig. 6.7 Importance of cooperation in integrated coastal management (after Lohmeyer, 1998).

zation by ICM are (1) governments must legally allow harmful side-effects caused by firms to be regulated by appropriate environmental conditions in accordance with the principle that the person who causes damage must bear the cost, so that development efforts of adjacent sectors do not impede one another; and (2) the rights of use must be classified in order to find investors for natural resource utilization (Lohmeyer, 1998).

The active participation of the beneficiaries and of the population concerned is regarded as the most important factor in an effective management for sustainable development of the coastal region. The basis of good management should be the traditional habits of the coastal area inhabitants, their sense of what is right and wrong, and traditions of how, when, and against which 'legitimate' background they make use of the resources for themselves.

RANGELANDS AND SUSTAINABLE LIVELIHOOD

Our understanding of the linkages between changes in the state of rangelands and the impacts on people's livelihoods is meagre, e.g., about the impact on land productivity and people's income of rangeland changes. We also do not know whether rangeland changes are primarily driven by human or by physical factors.

Like other ecosystems, rangelands change due to human and natural factors, and the changes can have profound impacts on people's livelihoods and rural and even national development. Global changes can include temperature increases, changes in rainfall patterns, and changes in biodiversity and land use. In communal rangelands, land use changes appear to be the most important ones. The relationships are summarized in Figs. 6.8 and 6.9.

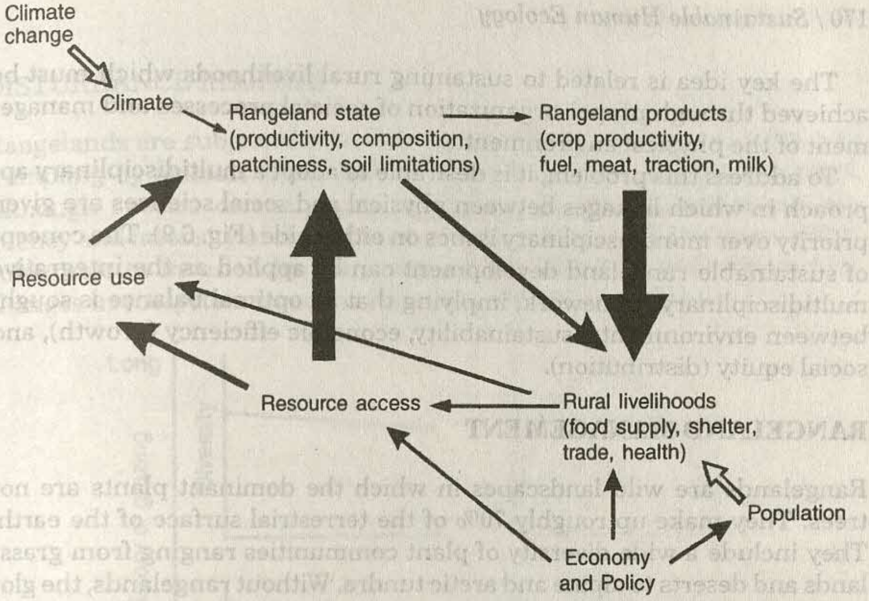
Climate change
Climate
Rangeland state (productivity, composition, patchiness, soil limitations)
Rangeland products (crop productivity, fuel, meat, traction, milk)
Resource use
Resource access
Rural livelihoods (food supply, shelter, trade, health)
Population
Economy and Policy

Fig. 6.8 Processes underlying rangelands/human interactions in subsistence pastoral systems (after Odada *et al.*, 1996).

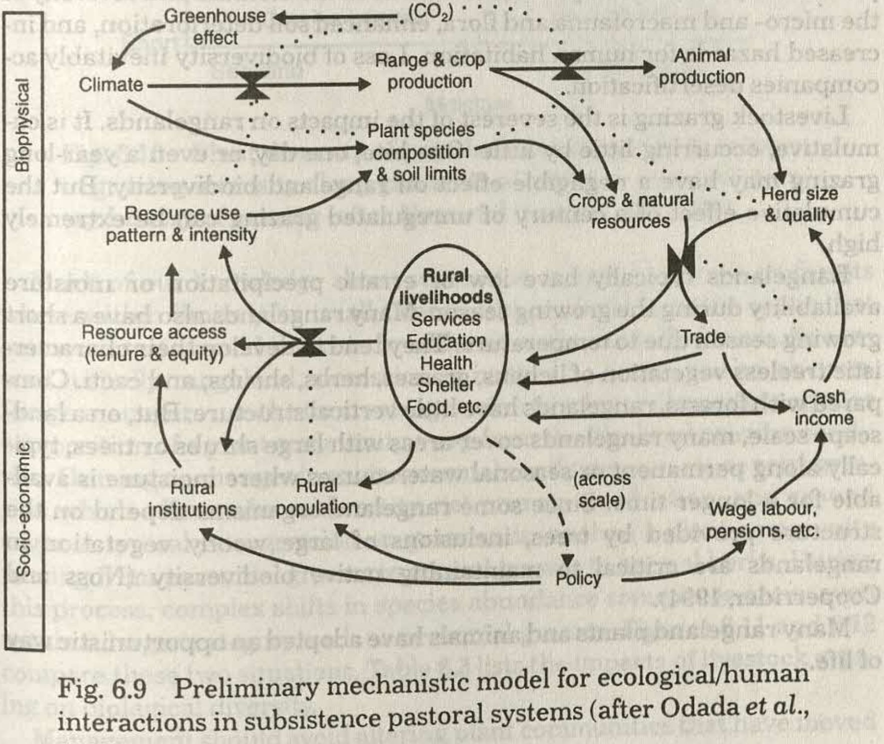

Fig. 6.9 Preliminary mechanistic model for ecological/human interactions in subsistence pastoral systems (after Odada *et al.*, 1996).

The key idea is related to sustaining rural livelihoods which must be achieved through proper organization of societal processes and management of the physical environment.

To address this problem, it is desirable to adopt a multidisciplinary approach in which linkages between physical and social sciences are given priority over monodisciplinary issues on either side (Fig. 6.9). The concept of sustainable rangeland development can be applied as the integrative multidisciplinary framework, implying that an optimal balance is sought between environmental sustainability, economic efficiency (growth), and social equity (distribution).

RANGELAND MANAGEMENT

Rangelands are wild landscapes in which the dominant plants are not trees. They make up roughly 70% of the terrestrial surface of the earth. They include a wide diversity of plant communities ranging from grasslands and deserts to alpine and arctic tundra. Without rangelands, the global biodiversity would be quite incomplete.

Many rangelands are being degraded or converted to arid (desert) areas. Desertification involves the impoverishment of arid, semiarid, and some other ecosystems by the impact of man's activities and drought, and results in certain changes in these ecosystems that can be seen by reduced productivity of desirable plants, alterations in the biomass and diversity of the micro- and macrofauna and flora, enhanced soil deterioration, and increased hazards for human habitation. Loss of biodiversity inevitably accompanies desertification.

Livestock grazing is the severest of the impacts on rangelands. It is cumulative, occurring little by little. One bite, one day, or even a year-long grazing may have a negligible effect on rangeland biodiversity. But the cumulative effect of a century of unregulated grazing can be extremely high.

Rangelands typically have low or erratic precipitation or moisture availability during the growing season. Many rangelands also have a short growing season due to temperature. They tend to develop their characteristic treeless vegetation of lichens, grasses, herbs, shrubs, and cacti. Compared with forests, rangelands have little vertical structure. But, on a landscape scale, many rangelands cover areas with large shrubs or trees, typically along permanent or seasonal watercourses where moisture is available for a longer time. Since some rangeland organisms depend on the structure provided by trees, inclusions of large woody vegetation in rangelands are critical to maintaining native biodiversity (Noss and Cooperrider, 1994).

Many rangeland plants and animals have adopted an opportunistic way of life.

DISTURBANCE REGIMES

Rangelands are subjected to a wide variety of disturbances, e.g., fire and trampling by animals. Disturbances interact in complex unknown ways. Although species diversity may be highest at some intermediate frequency and intensity of disturbance, disturbances can make communities vulnerable to invasion by exotic species (see Fig. 6.10) with concurrent changes in ecosystem structure, function, and composition.

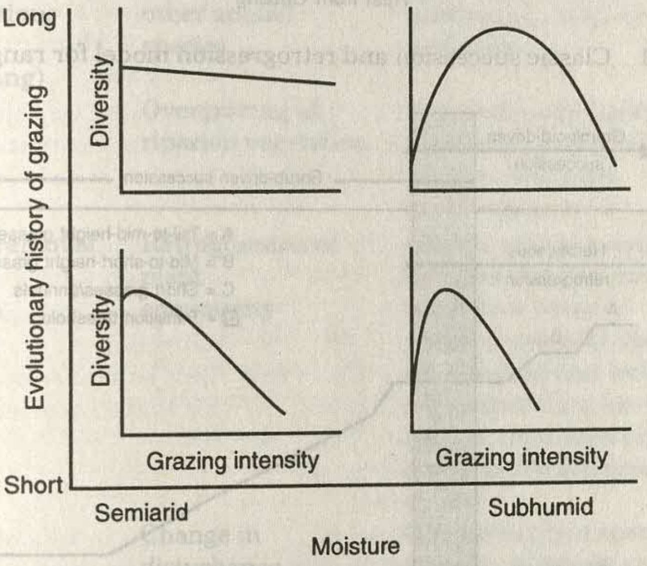

Fig. 6.10 Plant diversity of grassland communities in relation to grazing intensity along gradients of moisture and evolutionary history of grazing (after Noss and Cooperrider, 1994).

Much of our knowledge about succession is based on work on forests where within limits it is usually linear and predictable in the sense that cutover forests would revert to brushlands and eventually forests. In contrast, usually rangeland succession is neither so linear nor so obvious. Range managers use the term retrogression to refer to changes in species composition of a plant community away from the idealized pristine condition. Grazing or changes in environmental conditions can cause retrogression which often reduces diversity, net primary production, and ground cover. A typical retrogression on grasslands involves a plant community moving from perennial grasses to annual grasses to annual herbs. During this process, complex shifts in species abundance sometimes occur even within a larger category such as perennial grasses. Figures 6.11 and 6.12 compare these two situations. Table 6.3 lists the impacts of livestock grazing on biological diversity.

Management should avoid altering plant communities that have moved

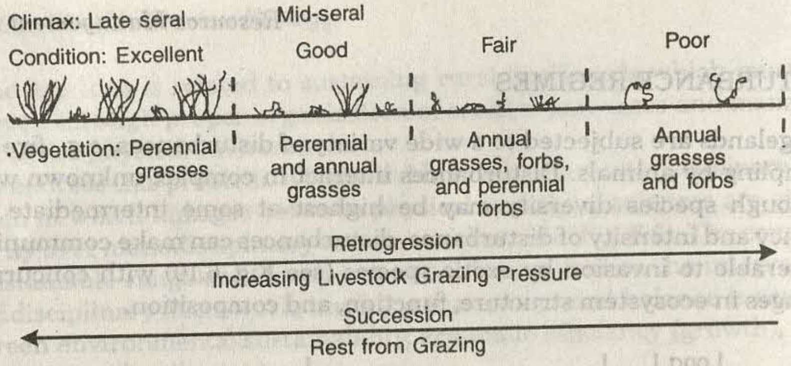
Climax: Late seral
Mid-seral
Condition: Excellent
Good
Fair
Poor
Vegetation: Perennial grasses
Perennial and annual grasses
Annual grasses, forbs, and perennial forbs
Annual grasses and forbs
Retrogression
Increasing Livestock Grazing Pressure
Succession
Rest from Grazing

Fig. 6.11 Classic succession and retrogression model for rangelands.

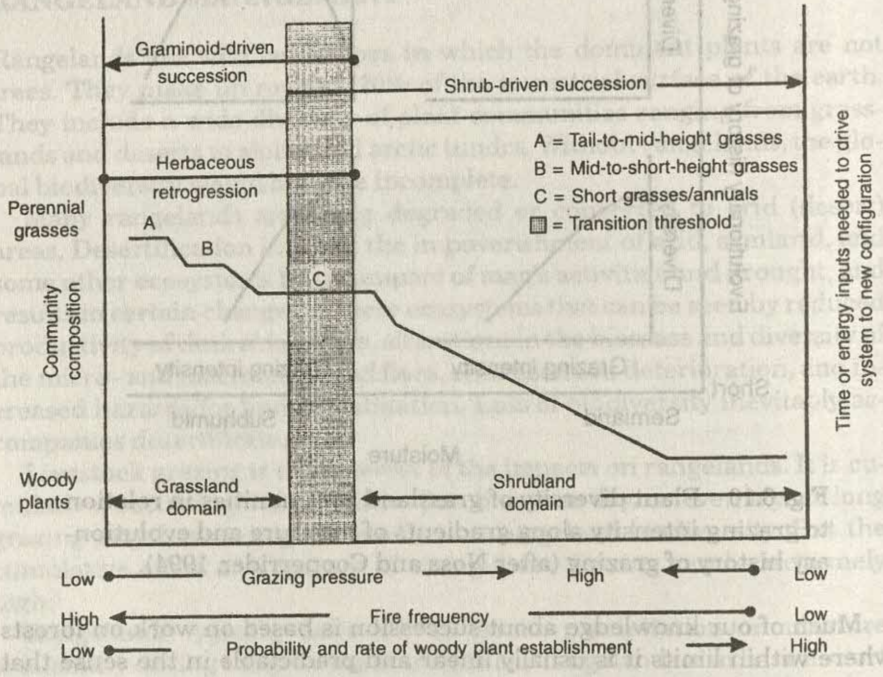
Graminoid-driven succession
Shrub-driven succession
Herbaceous retrogression
A = Tail-to-mid-height grasses
B = Mid-to-short-height grasses
C = Short grasses/annuals
▨ = Transition threshold
Perennial grasses
A
B
C
Community composition
Time or energy inputs needed to drive system to new configuration
Woody plants
Grassland domain
Shrubland domain
Low
Grazing pressure
High
Low
High
Fire frequency
Low
Low
Probability and rate of woody plant establishment
High

Fig. 6.12 Conceptual changes in community structure as a function of grazing pressure pushing a community beyond a threshold. Within the grassland domain, grazing changes composition and productivity of herbaceous species while decreasing fire frequency and intensity, thereby increasing probability of woody plant establishment. Reduced grazing pressure before a critical threshold takes succession toward higher-condition grasslands but if sufficient numbers of woody plants become established, shrub-driven successional processes tend to predominate and the site changes toward a new steady-state configuration. Once in the shrubland or woodland domain, the site will not revert to grassland after grazing has ceased, especially if the displaced grasses had originally established under a different climatic regime. Human manipulation can alter grass-shrub mixtures, but subsequent succession may result in a rapid return to a community dominated by woody plants. (After Noss and Cooperrider, 1994.)

Table 6.3 Impacts of livestock grazing on biodiversity (after Noss and Cooperrider, 1994)

Grazing/Other activity	Primary effect	Secondary and tertiary effects
Selective grazing/ overgrazing of individual plants	Decreased viability of individual plants	Plant decadence and death over time; species loss from plant community; extirpation; extinction
Selective grazing of most nutritious forage (high grading)	Loss of forage for other animal species	Decreased density of native herbivores, carnivores, and omnivores
	Overgrazing of riparian vegetation	Vegetation and habitat loss in riparian areas; increased erosion; degraded hydrological cycle
Excessive removal of primary production	Retrogression of plant community	Shift in animal community; reduced stability and vegetative cover of plant community; decreased interception and infiltration of precipitation; increased run-off; increased erosion and degraded hydrological cycle
	Change in disturbance cycles—especially decreased frequency and intensity of fire	Change in plant community, increase in woody species, decrease in other species; extirpation; extinction; impairment of nutrient cycling; impoverished production for all organisms
Trampling of ground around water-holes and shaded areas	Compaction of ground	Decreased infiltration; increased run-off; increased erosion
	Erosion of banks	Decreased bank stability of streams; increased sedimentation and erosion; degraded hydrological cycle
Livestock watering	Fouling and contamination of water	Diseases in native animals
	Water usurpation	Less water available for native wildlife in arid regions

Table 6.3 Impacts of livestock grazing on biodiversity (after Noss and Cooperrider, 1994) (cont.)

Grazing/Other activity	Primary effect	Secondary and tertiary effects
Importation of disease	Disease transmission to native wildlife	Reduced viability of native wildlife; extirpation; extinction
Presence of livestock on range	Avoidance of areas by native wildlife	Decreased effective habitat available for native wildlife; depressed abundance of native wildlife; extirpation; extinction
Fencing	Barriers to native wildlife	Decreased wildlife and its habitats; extirpation
	Injury to individual animals	Death of individual animals
Water development	Usurpation of water used by native wildlife	Decline in wildlife populations where water is limiting; extirpation; extinction
	Creation of sacrifice areas of heavy trampling and annihilation of vegetation	Less habitat areas available for wildlife species
	Spreading of livestock impact into new areas	Increase in area of livestock grazing impact
Salting	As in Water development	As in Water development
Roads	Increase in human access to sites	Greater human disturbance; decreased abundance of vulnerable species; extirpation; extinction
	Soil disturbance	Increase in invasion of exotic species, decrease in native species
Predator control	Decreased density of native carnivores	Extirpation/extinction of keystone predators; disruption of biotic community
Vegetation manipulation	Removal of vertical structure	Decrease in animal species richness and diversity

Table 6.3 Impacts of livestock grazing on biodiversity (after Noss and Cooperrider, 1994) (cont.)

Grazing/Other activity	Primary effect	Secondary and tertiary effects
Vegetation manipulation—ploughing and seeding	Soil exposure and disturbance	Increased invasion by exotic plant species; decreased abundance of native species; disruption of soil community; loss of native plant and animal species richness
	Introduction of exotic (seeded) plant species	Decreased density of native species
Vegetation manipulation—burning	Removal of vertical structure richness and diversity	Decrease in animal species
	Loss of nutrients from system	Decreased productivity of biotic community
	Soil exposure and disturbance	Increased invasion by exotic plant species; decreased abundance of native species; disruption of soil community; loss of native plant and animal species richness

beyond thresholds but not yet into another steady state; these communities should receive a high priority for restoration to a stable state.

The biodiversity of many rangelands is threatened by such factors as mining, suburban encroachment, roads, water diversions, and livestock production.

Selective grazing combined with the limited tolerance of some plant species to grazing can result in marked shifts in species composition of rangeland plant communities. With heavy and continuous grazing, the most palatable and nutritious plants first become weakened, fail to reproduce, and die, ultimately disappearing from the community. Other plant species that are less palatable or more tolerant of grazing, e.g., annual grasses, annual forbs, and exotic species, usually increase in the area.

The shift in plant community composition with grazing means retrogression which typically involves a reduction in perennial grasses accompanied by increases in less palatable annual grasses and herbs.

7

Land Use and Land Cover Changes

INTRODUCTION

Land use and land cover change is one of the central and core issues in the study of global environmental change. The alterations it effects in the surface of the earth have strong implications for sustainable development and livelihood systems and also contribute to change in the biogeochemical cycles of the earth, affecting the atmospheric levels of greenhouse and other trace gases. Any meaningful understanding of the nature of land use/cover change and its impact requires the joint efforts of natural and social scientists because of the expertise of each in certain key facets of the topic. A proper understanding in this context can come only from an interdisciplinary approach to the subject. There are five important questions that may be asked:

(1) How has land cover changed by human use over the last few centuries?

(2) What are the major human causes of land use change in different geographical and historical contexts?

(3) How will changes in land use affect land cover in the next few decades?

(4) How do immediate human and biophysical dynamics affect the sustainability of specific types of land use?

(5) How would changes in climate and global biogeochemistry affect both land use and land cover, and vice versa?

Improved understanding of the following may help answer these questions: (1) driving forces (exogenous variables) of land use as they operate through the land manager; (2) land cover implications of land use; (3) spatial and temporal variability in land use/cover dynamics; and (4) regional and global models and projections of land use/cover change.

There is a distinction between land use and land cover. Land cover change involves both conversion and modification. As land use involves both the biophysical manipulation of the environment and the purpose of the management processes, the term land use should be considered to refer to both processes, unless explicitly indicated otherwise. Driver(s), driving force(s), and forcing function(s) are synonyms that refer to what are known in some fields as exogenous variables.

Land use and land cover change can contribute significantly to earth-atmosphere interactions and biodiversity loss, is a major factor in sustainable development and human responses to global change, and is important to integrated modelling and assessment of environmental issues in general (Table 7.1).

Table 7.1 Some global change themes which require information on land use/cover change (after Turner *et al.*, 1995)

- Land cover-atmosphere interactions
  - Biogeochemistry
  - Atmospheric chemistry
  - Water and energy
- Biodiversity
  - Ecosystem structure and function
  - Species and genetic diversity
  - Land cover fragmentation
- Sustainability issues
  - Soil use and erosion rates
  - Soil nutrient maintenance
  - Water use
  - Agroecological potential/'support' capacity
  - Rural planning
  - National and international policy
- Response to global climate change
  - Land sensitivity to climate change
  - Land use for mitigation
- Integrated modelling and assessment

Though highly important, land use and land cover change is very poorly understood. The long-term global character, extent, and rates of changes in land cover and some land uses are known in rough outline, and uncertainty and error are relatively high (Meyer and Turner, 1994). Recent use of more precise, geographically-referenced data on cover and use has allowed improved analysis. Modelling the dynamics of land use and land cover change, however, has to some extent suffered by the considerable variation in those dynamics across physical and social settings. Global aggregate assessments based on simple assumptions miss the target for large sections of the world, while local and regional assessments are too specific to be extrapolated to wider scales.

FEEDBACKS AND HUMAN RESPONSES

The highly complex, interactive system of land use and land cover change and global environmental change link human action to use/cover change to environmental feedbacks to their impacts and human responses. The system becomes further complicated when the linkages occur at different spatial and temporal scales. The outflow of soil nutrients, for example, has immediate impacts on land productivity, vegetation changes, and soil erosion, mid-term impacts on landscape fragmentation and land productivity, and also possibly long-term impacts on climate change (Turner *et al.*, 1995). Several human driving forces (e.g., population and development), mediated by the socio-economic setting (market economy, resource institutions) and influenced by the existing environmental conditions, lead to an intended land use such as livestock herding of an existing land cover (e.g., forest) through the manipulation of the biophysical conditions of the land (Turner *et al.*, 1995).

Manipulations such as cutting and burning are referred to as proximate sources of change (to distinguish them from the underlying human forces of change). These actions may either convert the existing cover, in this case by cutting, burning, and planting, to create a grassland, or modify it by introducing new grasses into existing pastures. These land cover changes act as sources or in turn affect the use-cover relationship. These feedbacks, as well as the changes in the land, also themselves affect the driving forces and the social setting in which they operate, thereby altering the intended land use (Turner *et al.*, 1995).

DYNAMICS AND LINKAGES

Both the terrestrial (land) covers of the earth and their changes are central to a large number of the biophysical processes of global environmental change. Land cover is the biophysical state of the earth's surface and immediate subsurface. Changes in land cover include changes in biotic diversity, and run-off and sedimentation rates. Land covers and their changes are sources and sinks for most of the material and energy flows sustaining the biosphere and geosphere, including trace gas emissions and the hydrological cycle (Holligan and DeBoois, 1993).

Contemporary land cover is changed mostly by anthropogenic activity. Land use involves both the manner in which the biophysical attributes of the land are manipulated and the intent underlying that manipulation or the purpose for which the land is used. Forestry, parks, livestock herding suburbs, and farmlands are some classes denoting intent or purpose. In contrast, biophysical manipulation refers to the specific way in which humans treat vegetation, soil, and water for the purpose in question; some good examples are the cut-born-hoe-weed sequence in many slash-and-burn agricultural systems; the use of fertilizers, pesticides, and irrigation for mechanized cultivation on arid lands; and the use of an introduced grass species for pasture which can affect the movement of livestock in a ranching system (Turner *et al.*, 1995).

ENVIRONMENTAL IMPACTS OF LAND COVER CONVERSION

Man has been altering terrestrial ecosystems ever since he started using fire to hunt, and started domesticating plant animals and plants. Such change increased particularly strikingly in deforestation and the transoceanic movement of species (Crosby, 1986). Though substantial in spatial scale, magnitude, and pace, these changes are trivial in comparison to those produced by modern industrial society. Today, land cover changes of many kinds are truly global in spatial scale and magnitude and rapid, if variable, in pace; some of them are large enough to contribute significantly to changes in global biogeochemical flows.

From the start of the Industrial Revolution till the early part of the twentieth century, major changes in land cover were centred primarily in the mid-latitudes of the Northern Hemisphere (Turner and Butzer, 1992). During the latter half of the twentieth century, the major land cover changes occurred in the tropics, and cropland and grassland/pasture expansion, deforestation, and urbanization increased rapidly.

Of course, land cover changes (and therefore land use changes) are also environmentally significant in their own right. They can either degrade or enhance the land's capacity for sustained use and ability to regain its original cover. In some cases, land cover changes, or their impacts, become so strong or extensive that they can be readily identified as global change in themselves. Biodiversity loss is one example. Land cover change has led to grave losses in species numbers and varieties all over the world. Ecosystem structure and function, long-term ecological processes, and genetic diversity are also at risk in biodiversity loss. Biodiversity losses occur at multiple levels (landscape, ecosystem, species, gene) as well as in many dimensions (e.g., structural and functional), and hence are important for the structure and function of large-scale ecological processes, with implications for land use as well as other forms of global change (Schulze and Mooney, 1993).

IMPACTS ON BIOGEOCHEMICAL CYCLES

All through history, natural systems have been converted to agriculture and other human uses of the land. This has resulted in a net release of carbon dioxide to the atmosphere (Houghton and Skole, 1990) roughly equivalent to the release from fossil fuel burning over the last 150 years, although the current release of carbon dioxide from land cover conversion is approximately 30% of fossil fuel combustion (Turner *et al.*, 1995).

Both land cover and land cover change data are important for determining the biogeochemical cycling of carbon, nitrogen, and other elements at regional to global scales. The estimates of carbon released from land clearing and biomass burning combined with the estimates of oceanic uptake of carbon cannot now be reconciled in a balanced global budget as the land estimates are either incorrect or incomplete (Turner *et al.*, 1995).

LAND USE LINKS TO LAND COVER

Land cover is susceptible to change by natural processes. Climatic variations affect terrestrial ecosystems globally while volcanic eruptions and changes in river channels or sea level exert localized impacts. The world's land cover changes of the present and the recent past are overwhelmingly the result of human action, of activities largely aimed at modifying or converting land covers for the purposes of production and, to a lesser extent, settlement. These activities constitute land use (Turner *et al.*, 1995).

Every major type of land use has grown substantially through human history and particularly since the Industrial Revolution. In recent years, agriculture and livestock production have slowed in areal expansion globally, while settlement expansion is escalating (Berry, 1990). During the next few decades, agriculture is likely to shift from expansion towards intensification, while urban areas will continue to grow (Ruttan, 1994). Moreover, much of world's prime agricultural lands will be increasingly influenced by local atmospheric pollution (Chameides *et al.*, 1994).

IMPACTS ON SUSTAINABILITY

Changes in land use and land cover also have crucial environmental implications independent of the global variety, such as direct use-cover impacts from soil degradation, surface run-off alterations, and draw-down in groundwater. These kinds of changes confront the land manager on a daily basis. Their impacts on, and sensitivity to, global environmental change can be termed issues of sustainability (Turner *et al.*, 1995). Increasingly it is being felt that land use/cover change is central to these sustainability issues which link to developmental ones. Many of the problems associated with land use/cover sustainability (e.g., groundwater depletion) can trigger large-scale environmental problems with strong impacts on land use/cover dynamics (Chameides *et al.*, 1994). The sustainability of any land use is not only connected to the environmental attributes of the land and the management policies employed on it, but also to the socio-economic condition of the land manager (Brookfield and Paddoch, 1994).

Analysis of land use/cover change requires cross-scale dynamics and strong historical dimension including both human history and natural history.

Three dimensions of drivers, viz., socio-economic, biophysical, and land management (proximate causes), are relevant to land use/cover change, two of which involve adaptive agents and systems that respond to and sometimes anticipate changes in the other sphere (see Fig. 7.1). Integration of the three spheres, therefore, is necessary. There is need to compare geographically different but analytically similar land use situations along these three dimensions. Each of the dimensions is implicitly multiscaler, though in the context of global environmental change, the modalities of land management tend toward the microscale, whereas the bio-

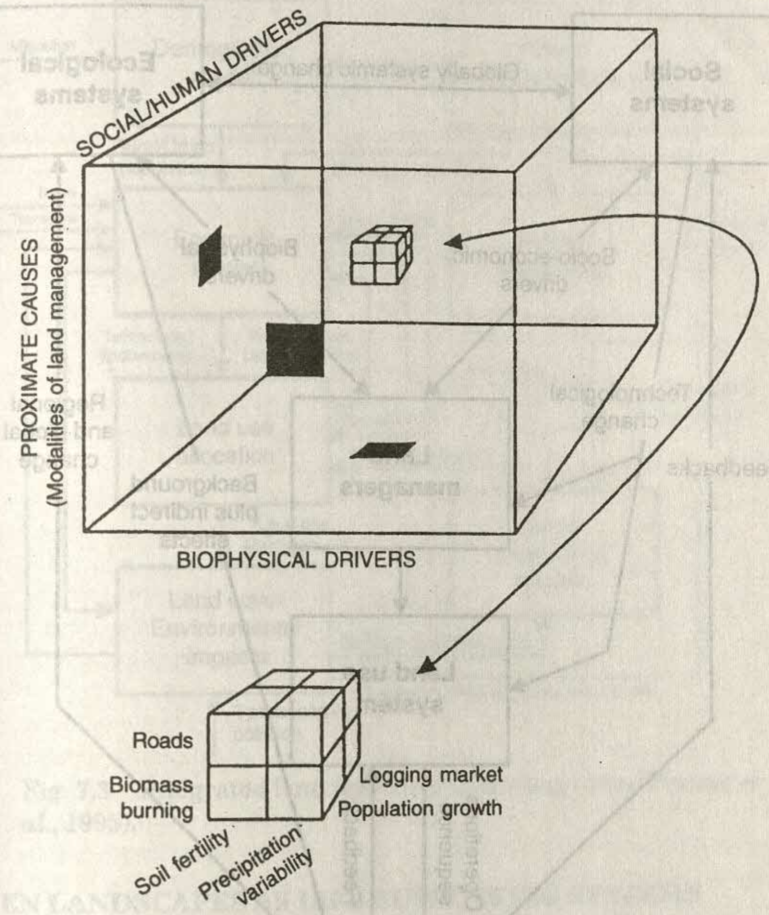

Fig. 7.1 Three dimensions of driving forces of land use/cover change (after Turner *et al.*, 1995).

physical and social forces are large-scale processes expressing themselves in different ways (see Turner *et al.*, 1995) across temporal and spatial scales (see Figs. 7.2, 7.3).

Land cover becomes changed in multiple ways, for instance, as a result of (1) independent changes in biophysical drivers (e.g., climate and atmospheric change, natural erosion and deposition); and (2) human activity, either (a) direct (e.g., deforestation) or (b) mediated through the biophysical realm (e.g., groundwater withdrawal, leading to a lowered watertable).

SPATIAL SCALE ISSUES

Any good understanding of the local, regional, and global dynamics of land use/cover change requires crossing of spatial and hierarchical (as well as temporal) scales (Fig. 7.2). Regrettably, our current understanding of the

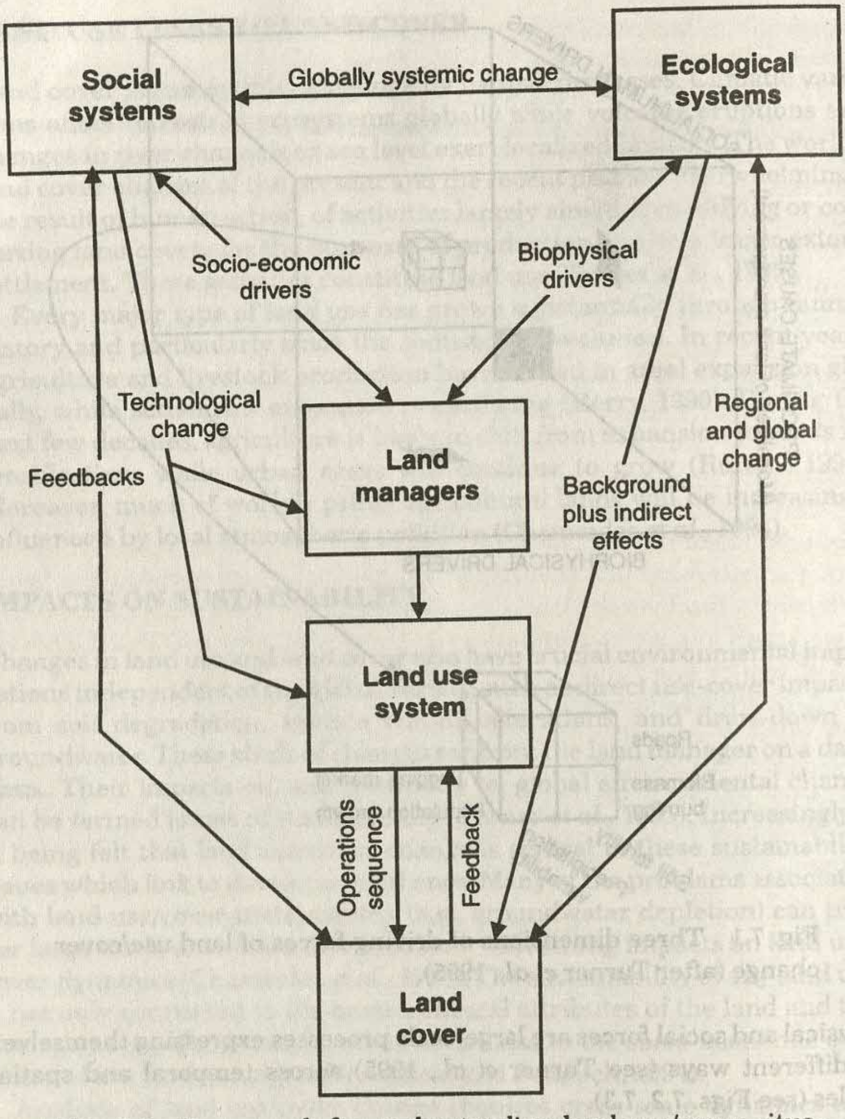

Fig. 7.2 Framework for understanding land use/cover situations (changes) (after Turner *et al.*, 1995).

links between scales is quite poor. Changing the spatial scale of the analysis can change the result. Many global analyses identify variants of the so-called PAT (population, affluence, technology) variables showing the strongest statistical correlations with environmental change (Rudel, 1989), implying that the particular/specific variables may be the underlying driving forces of change.

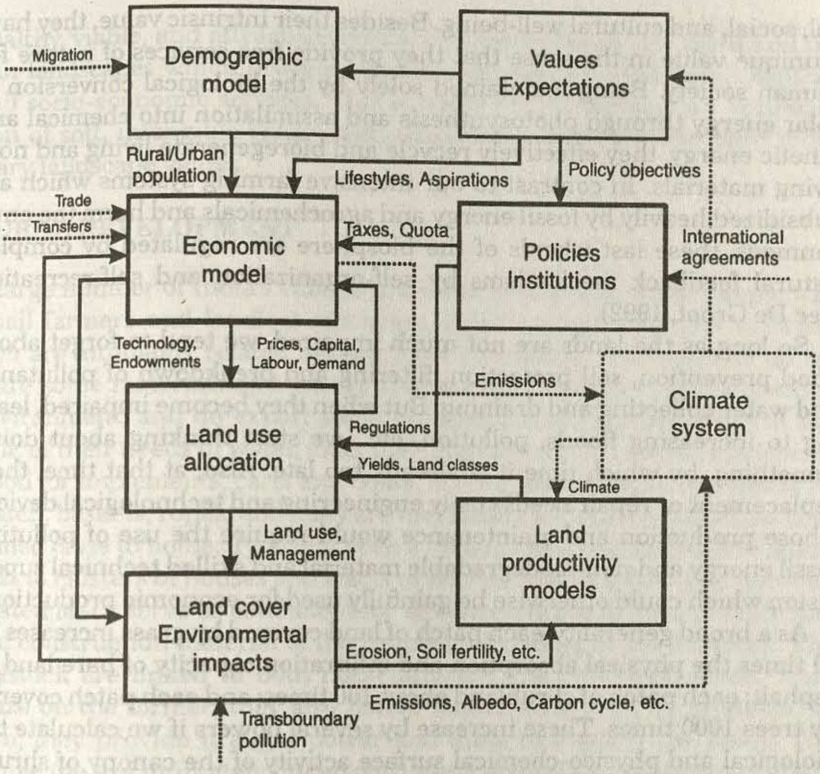

Fig. 7.3 Integrated land use/cover modelling (after Turner *et al.*, 1995).

OPEN LANDSCAPES AS LIFE-SUPPORTING SYSTEMS

In many countries, the common practice has been to regard as wastelands all the open and mostly untillable landscapes which are neither cultivated nor designated as nature reserves or planted forests. This reflects the idea that land is wasted if it is not converted into more profitable purposes. This term has been used in the evaluation of open spaces, such as sand-dunes, wetlands and uplands, for housing and highway construction by economists and politicians (see Westman, 1985; Naveh, 1997). Decisions are guided almost exclusively by short-sighted economic cost/benefit considerations and ignore the fact that we live in the higher, supersystem of our total human ecosystem in which humans and all other living organisms are integrated with their total physical, natural, socio-economic, and cultural environments.

If one takes total human ecosystem as a yardstick for land use decisions, then all open, non-cultivated lands covered by natural vegetation, which have not been destroyed completely, or whose original structure and function cannot be at least partly restored, should be marked as natural life-support systems fulfilling several vital functions for humankind's physical, social, and cultural well-being. Besides their intrinsic value, they have a unique value in the sense that they provide free services of nature for human society. Being maintained solely by the biological conversion of solar energy through photosynthesis and assimilation into chemical and kinetic energy, they effectively recycle and bioregenerate living and non-living materials. In contrast to our intensive farming systems which are subsidized heavily by fossil energy and agrochemicals and harm the environment, these last islands of the biosphere are regulated by complex natural feedback mechanisms by self-organization and self-recreation (see De Groot, 1992).

So long as the lands are not much impaired, we tend to forget about flood prevention, soil protection, filtering and breakdown of pollutants, and water collecting and draining. But when they become impaired, leading to increasing floods, pollution, etc., we start thinking about doing something, by which time it is already too late. Also, at that time, their replacement or repair needs costly engineering and technological devices whose production and maintenance would require the use of polluting fossil energy and non-biodegradable material and skilled technical supervision which could otherwise be gainfully used for economic production.

As a broad generality, each patch of land covered by grass increases by 10 times the physical absorption and infiltration capacity of bare land or asphalt; each patch of shrubland about 100 times; and each patch covered by trees 1000 times. These increase by several powers if we calculate the biological and physico-chemical surface activity of the canopy of shrubs and trees, functioning as powerful biological filters and green lungs.

Vester (1985) calculated the economic replacement value of the biological, ecological, socio-economical, and cultural services provided in Germany by an average single tree as being worth 1675 DM. This is 200 times greater than its value for timber alone. The German economy would have to spend some 4200 billion DM annually to replace these functions and free services.

However, it may be borne in mind that not everything which can be counted counts, and several things that cannot be counted may count. According to De Groot (1992), a change in the attitude of economists and politicians in favour of long-term sustainability is far more important than making an artificial yardstick for measuring all economic benefits of environmental functions.

Naveh and Lieberman (1994) distinguished between "hard" landscape values which provide marketable goods or can be evaluated in money terms, and "soft" values that are economically non-rich.

The narrow and short-sighted monetary evaluations in environmental cost/benefit calculations and land use decisions need to be replaced by broader ecological and socio-economic functional evaluations of the soft and hard values provided by these landscapes.

According to Naveh (1997), in order to implement sustainable holistic land uses, regional master plans should be prepared as these can ensure healthy, viable, and attractive natural and agricultural, and rural and urban landscapes which provide combined biological, ecological, cultural, and socio-economic services. This is possible only through an optimization of soft, intangible values with non-economic riches and hard monetary landscape values.

RURAL DEVELOPMENT

A large number of India's villages are inhabited by ecosystem people, i.e., small farmers and landless labourers, tribals, shepherds, and artisans, who are intimately related to their local ecosystem. These people do acquire some materials and energy sources from outside their immediate environment, and do export some produce out of their locality, but the bulk of their needs of water, food, fuel, manure, fodder, herbal medicines, wood for implements, carts and boats, fencing and construction material, thatch, baskets, ropes, and mats are met locally and their production consumed close to home. Typically, such a system comprises cultivated lands, next to clusters of houses and tracts of non-cultivated lands. The non-cultivated lands serve as catchment for streams and ponds, and provide fuel and construction material to the people and grazing to the livestock. The livestock are linked to both non-cultivated and cultivated lands. They graze on the former; they also derive fodder from crop by-products. In turn, they provide draught power and dung to manure the fields. The people too are intimately linked with these ecosystem components, gathering their produce and contributing labour to mould them (Fig. 7.4).

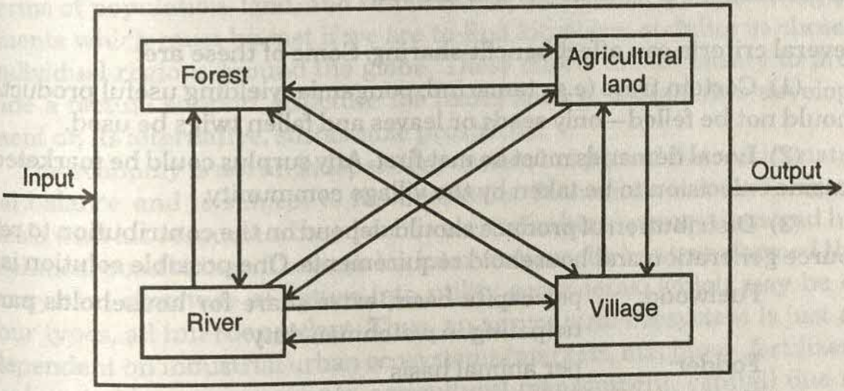

Fig. 7.4 Various interacting components of rural ecosystem (arrows denote interactions among components).

Planning for wasteland development must relate to the organization of land/water use. Since people's participation is a critical input, the basis of planning should be a hamlet/village in which people are in regular face-to-face contact. The cultivated land of such a village along with the non-cultivated lands and waters from which people derive many services also act as

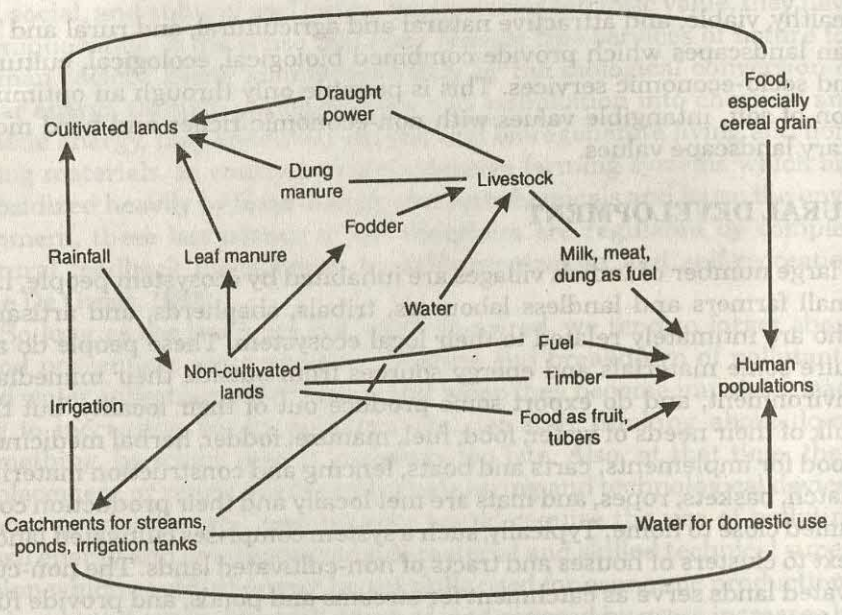

Fig. 7.5 Village ecosystem.

functional ecosystem units.

Figure 7.5 is a schematic sketch of the village ecosystem showing its components.

CRITERIA FOR SHARING BENEFITS

Several criteria can affect benefit-sharing. Some of these are:

(1) Certain trees (e.g., tamarind, pongamia) yielding useful products should not be felled—only seeds or leaves and fallen twigs be used.

(2) Local demands must be met first. Any surplus could be marketed outside—decision to be taken by the village community.

(3) Distribution of produce should depend on the contribution to resource generation and household requirements. One possible solution is:

Fuelwood: per capita basis, extra share for households participating in watchman duty
Fodder: per animal basis
Timber: per house basis
Leaf manure: per hectare basis
Water: per hectare or per capita basis

Another option is to distribute everything on per capita basis, equitably among all; even landless will get water which they can barter to farmers. A problem of this option is that it may encourage larger family sizes among the poor who are least able to support more children. The final decision should be left to the village community.

8

Economics and Environment

INTRODUCTION

The twentieth century has seen the rapidly-increasing production and, in many ways, extravagant use of energy to meet the ambitious demands of inhabitants of the advanced countries in every sector of their activity. A similar trend has caught on in many developing countries also. Whereas industrial wastes and the indiscriminate use of chemicals of all sorts have played havoc to the environment in the developed countries, in the developing countries, increasing population, poverty, water-borne diseases, and nutritional deficiencies and disorders have exerted negative impact on the environment. The large-scale damage to the global environment has already reached alarming level and mankind must change its present luxurious lifestyle to a sustainable form otherwise our children may not be able to live on the sick planet a few decades from now. All human activities need to be tuned for sustainable and environment-friendly development. The use of non-renewable resources cannot go on at the present rate in the advanced countries, nor can the current rates of environmental pollution in the developing nations.

Our long-term goal should be a sustainable prosperity for all. Concerted efforts are needed to examine quantitatively the detailed requirements in terms of population, land, and resource use, and handling of polluting effluents which must be met if we are to find long-term stability in chosen individual regions around the globe. These efforts are necessary to provide a factual support structure for issues such as sustainable development or, its alternative, sustainable prosperity.

The economy is not an independent system but part of the earth's natural balance and is subject to its limitations. Man as an economic agent deals with his resources, based on his mental/cultural perceptions and his technical possibilities. Through his interventions, he has transformed the ecosystem structure of nature into utility ecosystems, which may be of four types, all interdependent. Thus, an agricultural ecosystem is just as dependent on industrial urban ecosystems (markets, machines, fertilizers and pesticides, energy supply, agricultural management, capital) due to diverse input relations as, conversely, the urban ecosystems (food and water supply, disposal services) are dependent on the agricultural ecosystems. Local natural ecosystems are overlaid by regional, sometimes global, 'artificial' systems, and thus are interdependent. Economic behaviour has to be oriented toward the vitality and productive force of ecosystems.

The basic idea is that the economic agents of any given region (or of the world) may only consume as many renewable natural resources as will 'grow back' in nature, that is, as is sustainable by the ecosystem. Likewise, only the same amount of emissions may be released into nature as it can tolerate, without losing its processing capacity in the future. Another good way to define sustainable economic growth is the increase in real GNP (gross national product) per capita over time, the increase not being threatened by 'feedback' from either biophysical impacts (pollution, resource problems) or from any social disruption.

Sustainable economic behaviour means that people should be prepared to accept some losses or sacrifices in income and affluence, in favour of long-term advantages.

A war should be waged against those power structures which result from non-sustainable economic behaviour. Some small attempts have occasionally been made to introduce sustainability into economic models. The concept of sustainable price embraces, in addition to the current market price, the sustainable user costs (SUCs). These SUCs may be calculated as the difference between the optimum price and the price that corresponds to an amount that is ecologically sustainable in the long term; these costs escalate depending on the extent to which the natural resources have been either neglected or abused in the past. The idea of the term sustainable income may be understood from the equation

sustainable income = measured income
= household expenditure – value of residual pollution – depreciation of man-made capital – depreciation of environment capital.

Some attempts have also been made to design an environment- and welfare-related indicator of consumption by subtracting the costs for environmental protection from the national product. Welsch (1992) even proposed a macroeconomic environmental model to assess environmental protection activities in global economic accounting.

No doubt, modern technologies help relieve life's drudgery but they also carry social, economic, and ecological costs. This best known side-effect of technological development occurred following the advent of the Green Revolution, leading to a marked decrease in biodiversity and great increase in pesticide use. The miracle of stability in food production has now faded and biotechnology and genetic engineering are being hailed as chemical-free solutions to the problems created by the technology of the Green Revolution. Biotechnology has a major role in the selection and breeding of crops. The basic need is to conserve and improve hardiness, nutritional value, and yield of diverse crops used by the poor, so biotechnology can contribute much in these areas. Unfortunately, however, most research focuses on, for instance, gene transfer for pesticide resistance. Rotational and mixed cropping form the basis of sustainable and ecologically-balanced forms of agriculture and food security. Herbicide resistance excludes this possibility. The traditional cropping patterns have also been successful in keeping pest outbreaks in check. Since many of the pests are specific to particular plants, planting of different crops in different seasons and different years causes large reductions in pest populations. These cropping systems also require less irrigation, which prevents the spread of the pests.

In developing countries, high priority needs to be given to enhance multiple-cropping and rotation techniques, rationalization of the use of wild plants in local diets, and improvement of traditional crop protection practices. Using science in general to enhance the sustainable production systems appears far more important than looking for instant solutions affording short-term gains.

ECONOMY/ENVIRONMENT INTERFACE

It is now generally agreed that the integration of economic and environmental concerns is a key environmental challenge facing governments. There is a fundamental link between economic growth and the environment; economic and environmental policies cannot be made and implemented in isolation. Environmental considerations must be brought to bear systematically on economic policy-making, and, conversely, sound economic analysis of costs and benefits and their distribution, coupled with scientific assessment of relative risks, should be the basis for fixing priorities among various environmental goals and choices. Compatibility between environmental and sectoral economic policies should be the central objective of policy makers, and should be subject to periodical monitoring and evaluation. Economic instruments, used in conjunction with regulations, are important tools for achieving policy integration, and international consultation and coordination is essential to ensure that national environmental policies, whether regulatory or market-based, do not impose constraints to national competitiveness and international trade.

There has been much focus on developments in the environmentally-sensitive energy, transport, and agriculture sectors of the economy, and emphasis is being given to the linkages between environmental policy on the one hand, and fiscal, employment, and trade policies on the other.

ECOLOGICAL ECONOMICS

Ecology and economics have historically been treated as distinct disciplines. Each certainly borrowed theoretical concepts from the other, but they addressed separate issues, utilized different assumptions to reach answers, and supported different interests in the policy process. It is now high time that the two disciplines were brought together. Ecological economics offers an opportunity for economists and ecologists to interact with each other, to explore together new patterns of thinking, and to facilitate the formulation and implementation of new economic and environmental policies. So far, ecological economics has remained conceptually pluralistic, even while particular practitioners may prefer one paradigm

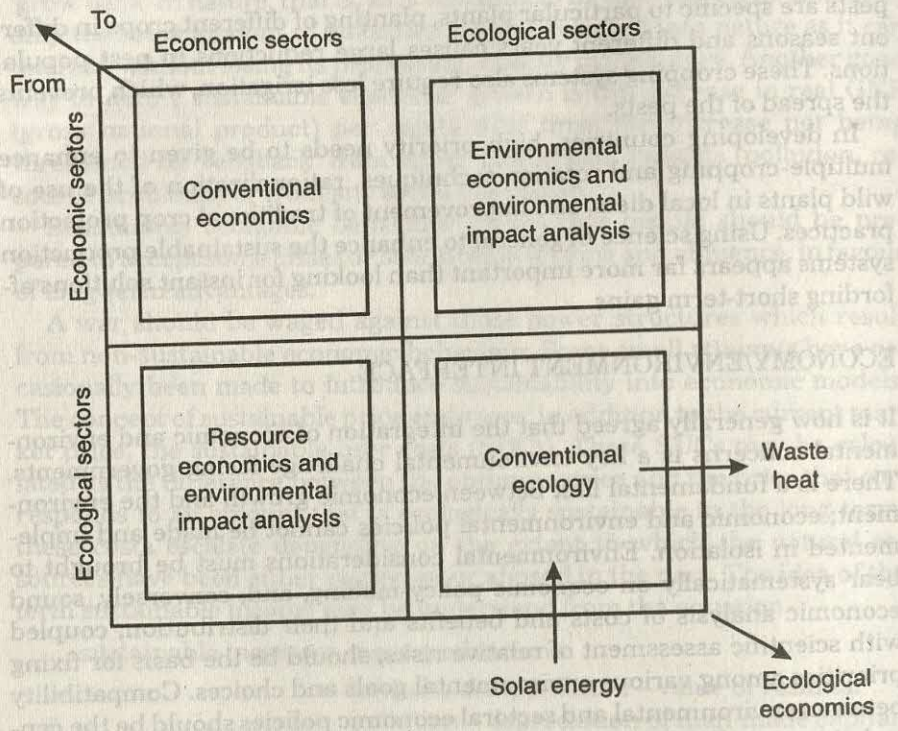

Fig. 8.1 Ecological economics, involving interactions between economics and ecological sectors. The overall system is driven by sun and dissipates waste heat. (After Costanza, 1991.)

over another (Norgaard, 1989; 1994). Figure 8.1 illustrates the linkages between ecology and economics.

Ecological economics has been evolving as a transdisciplinary exercise aimed at the sustainable management of the interconnected ecological and economic systems (Fig. 8.1), and founded on the fact that humanity is very much a part of nature (Folke *et al.*, 1993). The links between economic and ecological systems need to be better understood. Are current policies ecologically sustainable and economically efficient? The question relates to whether or not existing policies lead to an economically-efficient allocation of biotic resources. This can be judged by analyses of the role of policy in influencing the private cost of resource use. Policies that increase the gap between the private and social cost of resource use encourage inefficiency. The reason for loss of biodiversity is partly that biotic resources are neither properly considered nor accounted for under the existing policies (Burgess, 1993; Southgate and Clark, 1993). Although an economy can be both efficient and sustainable, economic efficiency does not in itself guarantee sustainability. The economic efficiency criteria do not necessarily match with biophysical limits and carrying capacity; the issue of scale has to be clearly recognized. Carrying capacity is related to the idea of resilience, i.e., the capacity of a system to recover from unpredictable perturbations. Keeping the development of socio-economic activities within the resilience of their ecological resource base—locally, regionally, and globally—poses a strong challenge for sustainability. Biodiversity has a role in this context for several ecosystems and their uses (Lugo *et al.*, 1993; Kumar, 1999). Loss of resilience means that limits for socio-economic development are approached more rapidly. Limits are not static, hence human behaviour in tune with the resource base, instead of working to degrade it, will not face limits as rapidly and thereby keep more options open for development.

In the new economic view, the environment is finite and the economy is a subsystem of the environment (Fig. 8.2).

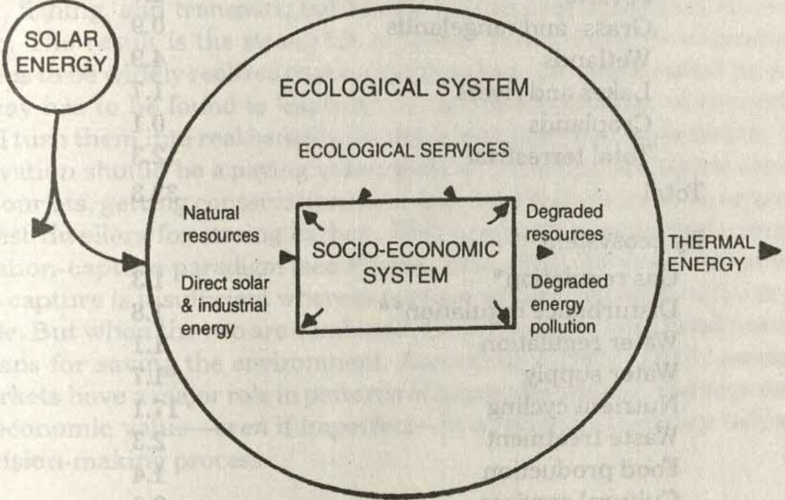

Fig. 8.2 Dependence of economy as part of its life-supporting environment on energy and natural resource inputs for production and consumption and on services generated by ecosystems, such as drinking water supply, nutrient recycling, soil generation. Being parts of ecosystems, species sustain those crucial services. If human societies do not recognize their place in the overall system, their activities will continue to cause losses in biodiversity, thereby reducing environmental support on which human welfare depends. (After Perrings *et al.*, 1992.)

MACROECONOMICS AND ENVIRONMENT

Costanza *et al.* (1997) attempted to price the services that the world's ecosystems provide to humans (Table 8.1). That price was $33 trillion per annum, with a confidence interval of some $16 trillion to $54 trillion. Given that the combined GNP of all the countries in the world was about $28

Table 8.1 The Costanza *et al.* (1997) estimates of annual global value of ecosystem services (after Pearce, 1998)

Service	Trillion $ (as in 1994)
By biome	
Marine	
Open ocean	8.4
Coastal areas	12.6
Total marine	21.0
Terrestrial	
Forests	4.7
Grass- and rangelands	0.9
Wetlands	4.9
Lakes and rivers	1.7
Croplands	0.1
Total terrestrial	12.3
Total	33.3
By ecosystem	
Gas regulation*	1.3
Disturbance regulation**	1.8
Water regulation	1.1
Water supply	1.7
Nutrient cycling	17.1
Waste treatment	2.3
Food production	1.4
Cultural services	3.0
Other***	3.6
Total	33.3

*Regulation of the chemical composition of the atmosphere.

**Mitigation of environmental fluctuations such as storms and floods.

***Includes climate regulation; erosion control and sediment retention; soil formation; pollination; biological control; provision of habitat, raw materials, and genetic resources; and recreation.

trillion in 1995, ecosystems would appear to be providing 1.2 times as much economic value as people are creating (World Bank, 1997). Without doubt, there are good reasons for attempting to place a monetary value on ecosystem functions. The environmental rationale arises from the widespread concern about loss of habitats and species and the continuing depletion of natural resources. The concern has not translated into any significant progress in conservation because modern environmentalism has failed to address the underlying economic causes of environmental degradation (Pearce, 1998). The benefits and gains from any conservation effort appear to be much smaller as compared to the economic returns to society from converting natural assets into commercial ones. Consequently, hotels and tourism replace pristine coastlines; tropical forests are burned to create new pasture and croplands; and roads are built through ecologically-valuable landscapes. The motive is the belief that people would be better off by giving up a natural asset. The erroneous belief comes from the fact that the services provided by ecological systems are not traded in markets and so have no readily perceived value. Because we do not buy and sell clean air, nutrient cycling, or carbon storage, the value of such services is naturally perceived to be zero. Governments all over the world make the odds against conservation even worse by merrily going on subsidizing irrigation water, energy, fertilizer, pesticides, agricultural output, fishing, and transport, but hardly any country subsidizes conservation. The result is the strong tilt in favour of economic development. It needs to be widely realized that ecosystems have economic value. And also a way has to be found to 'capture' the non-market values of ecosystems and turn them into real benefits for those who practise conservation. Conservation should be a paying venture either by selling ecological services to tourists, getting conservationists to buy land and preserve it, or paying forest dwellers for storing carbon. This approach exemplifies a demonstration-capture paradigm (see Pearce, 1995, 1998). Demonstration without capture is insufficient whereas capture without demonstration is possible. But when the two are combined, they become a potent and practical means for saving the environment. According to Daily (1997), economic markets have a major role in patterns of human behaviour. The expression of economic value—even if imperfect—in a common currency helps the decision-making process.

PRINCIPLES OF MONETIZATION

Value judgement is based on people's preferences that determine how the economy's resources are allocated. In a democracy, people show their preferences by voting in elections. Likewise, they do so by the particular goods and services they purchase. These preferences are measurable. Consumers' preferences are revealed by their willingness to pay (WTP). When one's WTP is less than the price of a good or service, one will not buy it; otherwise, one will. One's WTP, in turn, depends on income. Generally, the higher one's income, the greater one's WTP for major items. Consequently, there is an important difference between voting in an election and 'voting' in the market-place: the former follows the principle of "one person, one vote", the latter awards votes on the basis of income and wealth. Economists determine the overall social benefit of a particular good, service, or activity by measuring individuals' preferences for it and then aggregating them (Pearce, 1998). This is a useful way to decide about government spending: money should be spent only on some particular item if its social benefit exceeds its cost.

Another important tenet underlying economists' efforts to value environmental services is that this valuation should be done at the margin, that is, in terms of incremental changes instead of large ones. According to Daily (1997), just as it would be absurd to calculate the complete value of a man or woman on the basis of his or her wage-earning power, there is no absolute value of ecosystem services waiting to be discovered. The evaluation of trade-offs is based on estimates of the marginal value of ecosystem services (the value yielded by an additional unit of the service, all else being kept constant) to determine the costs of losing—or the benefits of preserving—a given amount or quality of services (Daily, 1997).

Marginal analysis is a basic principle of economics, particularly the determination of prices. Prices are determined in markets by the forces of supply and demand. Underlying the demand for any good or service is the satisfaction that the consumer obtains from it. Similarly, the producer's willingness to supply a good or service depends on its marginal cost of production (i.e., the cost of producing one additional unit). That cost reflects the marginal contributions to output of additional units of inputs (such as labour and capital). Whereas most economists can predict how a price will respond to small changes in the factors that determine it, few can predict in case of large changes. According to Pearce (1998), while quantifying the value of environmental services, Costanza *et al.* (1997) violated the foregoing principles.

Daly (1991) and Daily (1997) regarded the Costanza *et al.* (1997) attempt to value the world's ecosystem services as one of the first quantitative studies in the macroeconomics of the environment. It differs from virtually all prior economic studies of the environment, which were conducted at the microeconomic level. Microeconomics focuses on the behaviour of individuals, firms, or single industries. Macroeconomics focuses on economic activity overall, notably GNP and variables (such as employment and interest rates) that are closely related to it. Both approaches offer valuable insights, but they are fundamentally different in character. Pearce (1998) contended that the Costanza *et al.* (1997) efforts to value ecosystem services must be done at the margin and that they had violated this principle in deriving a total value for global ecosystem services. In response, Costanza *et al.* (1998) pointed out that the conceptual problems one encounters while going from the micro- to the macrolevel are exactly the same difficulties that one encounters in all macroeconomic analysis as far as the distinction between marginal and total values is concerned. What Costanza *et al.* (1997) did was to estimate the equivalent of a price (or marginal value) per hectare for each ecosystem service and then multiplied it by the quantity of the service currently being provided to obtain a macrototal. This is identical to what is done in conventional GNP accounting to derive the total value of marketed products. It is, of course, arguable that all macroeconomic accounting is flawed in this sense but then Costanza *et al.* (1997) may not be faulted for violating basic economic principles by following the standard practice.

Costanza *et al.* (1998) did not agree to the Pearce (1998) criticism that WTP is the only (or necessarily the best) way to assess economic value in all circumstances.

PRICES AND VALUES

Most economists can know the price of virtually everything and express it in some currency unit, but they do not know the value of anything. Values tend to vary widely from person to person and from generation to generation. Prices reflect incremental marginal costs. Gold trades for a higher price than does freshwater. Yet the value of all freshwater is infinite because nobody can survive without it. Prices are very incomplete measures of nature's value and do not convey the consequences of humanity's exponential growth. For economists, the challenge is how to assess an ecosystem's non-market values.

Ecologists have to grapple with extremely complex ecological interactions. When a forest is cut off, the price of adjacent homes will decline. The nearby streams become filled with sediment and lose their fish. Flowing to the sea, the sediment can destroy fish, beautiful corals, and some other valuable species. Forests act as a carbon sink. Their loss can accelerate global warming and sea level rise. Costanza *et al.* (1997) grouped such diverse services into 17 categories (the value of gas regulation, climate regulation through to cultural value) and classified the earth's surface into 16 biomes. They then estimated the 272 combinations one at a time. Many combinations have high value. Besides these, certain other combinations are valuable. For instance, mountains and deserts are culturally valuable but they seem to be absent from the estimated grand total of $33 trillion per year. Also absent are urban areas with city parks. Filling in these and the other similar omissions will certainly increase the foregoing estimate.

We use freshwater directly and the function of natural ecosystems in waste treatment is important and often overlooked. Current prices are a poor predictor of future value. The price of an essential resource such as water rises nonlinearly as it becomes scarce. We already use half of the available global supply of freshwater. In some areas, the situation is critical. The nonlinearities in the value of ecosystem services can have political as well as economic consequences.

A popular argument is that we must preserve biodiversity as a potential source of new medicines and genes for crop improvement. But cultural and recreational uses of nature may be even more valuable.

COSTING THE EARTH

There is no doubt that cooperation and collaboration between economists and ecologists is highly desirable for tackling environmental issues such as biodiversity conservation, climate change, and management of forests and fisheries. Till recently, such collaboration has involved a kind of unwritten hierarchy in which environmental and resource economists have tended to frame the problem, and ecologists have provided the basic data.

This hierarchy is now being challenged by two distinct schools of the new discipline of ecological economics. Broadly, none of the members of the two schools accepts ecology as merely an input into environmental and resource economics. They want trained ecologists to play a greater role in fixing conservation goals. The schools also agree that assigning a monetary value to environmental services can focus attention on the importance of environmental protection. But the similarities end there. One school intends to work within the parameters of neoclassical economics. The second desires ecological economics to grow as an entirely new discipline (Masood and Garwin, 1998).

Some issues that interest ecological economists are environmental impact assessments; costing ecosystem services (such as pollination of plants by insects); and factoring depletion of natural resources (such as gas and petroleum reserves) into national accounting systems. Some develop market-style incentives to help conserve natural ecosystems.

One school of ecological economics is strongly linked to the Beijer Institute of Ecological Economics in Stockholm. This Institute is governed by an equal number of ecologists and economists and publishes the journal *Environment and Development Economics*.

The second school of ecological economics revolves around the International Society for Ecological Economics (ISEE) which publishes the journal *Ecological Economics*. Its members have more diverse backgrounds, about two-thirds being ecologists or economists, and the rest coming from other fields. The ISEE was founded by economist Herman Daly who propagated the idea that there is a limit to how long the earth's natural resources can be consumed at the present rate—and that this limit is not far off. He feels that ways should be found to reduce human consumption, as measured by the rate of economic growth, but without reducing the quality of life. Many ISEE members question neoclassical economics. These members do not share the optimism of neoclassical economists that a combination of technology, regulation, and market mechanisms will suffice to solve problems such as energy and food shortages.

In assessing industrial pollution, a neoclassical economist would subtract the 'costs' of the pollution (e.g., in terms of climate change and damage to human health) from the 'benefits' measured in terms of industrial output and employment. He would then calculate a sustainable level of pollution, usually a quantity whose benefits are greater than the costs. In contrast, an ecological economist will factor in additional elements, such as the right of future generations to a clean environment. This will result in a level of acceptable pollution lower than that arrived at by the neoclassical economist.

Some members of the Beijer Institute of Ecological Economics are inclined to agree with the second school's overall aims, but most are unconvinced of the methods. According to David Simpson, who specializes in valuing biodiversity, most policy makers are concerned more with practical ways of managing resources sustainably than with developing new approaches to environmental problems. There is a virtually universal political consensus that economies need to grow, albeit sustainably (Masood and Garwin, 1998).

But, while the two schools of ecological economics may share common goals and ways of working, there is still a basic difference. Ecological economics aims to provide a framework for the equitable distribution of resources and property rights within the present generation of humans, between current and future generations, and between humans and other species. It has a clear social component. It may be the willingness or reluctance of economists to take this social agenda into account in their work on environmental issues that represents the sharpest division between the different schools.

Economic incentives are already being used to protect the natural environment and the 'services' it provides to society. These incentives can range from the tourist dollar to tradable pollution permits. They become more and more effective as natural amenities become scarce.

Conservation can lead to the avoidance of costs that would otherwise be incurred. For example, protecting watersheds from development is a relatively cheap way to provide clean, abundant water for downstream users. Globally, there may be an economic justification for conserving over 10% of the world's land area for its watershed value to urban water supplies. In this case, an economic incentive exists for preserving an ecosystem because it supports goods or services with a clear market value. These goods and services have the property of 'excludability'—it is possible to exclude people from consuming them, and so to make people pay for that consumption.

But many of the services provided to humans by ecosystems are non-excludable—they provide benefits to people who may never set foot in the ecosystem, or even be aware of its existence. Such services include the retention of soil and prevention of flooding by vegetated landscapes, and the role of birds and insects in pest control and pollination. In the extreme example of a shared benefit, the sequestration of carbon by a hectare of forest benefits all humans by offsetting greenhouse gas emissions. Because this landowner (supplying such services) does not get any compensation for the services, he has no economic incentive to conserve the resource.

The economist's solution to the problem of non-excludability takes the form of assigning an appropriate kind of property rights, in the same way that patents and copyrights protect knowledge. Analogous environmental examples can be grazing rights and fishing quotas. For maximum economic efficiency, these rights should be 'tradable', giving them a market value and creating incentives for conservation. Some governments address air pollution problems by means of emission permits, such as tradable sulphur dioxide emissions allowance (Masood and Garwin, 1998).

The recent Kyoto Protocol on climate change even provides not just for tradable carbon dioxide emission permits, but for permits to be given to countries that sequester an equivalent amount of carbon—for example, by reforestation. This could strongly affect the economics of forest conservation, because the Protocol allows developed countries to pay for forest conservation in developing countries. Growing forests might earn carbon sequestration credits at upto $800 per hectare per year.

MARKET-BASED CONSERVATION

Many ecosystem services have not yet become scarce enough to warrant a market-based conservation mechanism. In other cases, appropriate regulations are not yet in place to assign or enforce the relevant property rights.

One goal shared by most ecological economists is to develop a system of national accounting that covers environmental factors excluded from current definitions of gross domestic product (GDP).

The conventional assessment of GDP involves adding up all the final demands for goods and services produced annually by a country. Although widely used, GDP is much criticized by environmentalists on the grounds that it paints a misleading picture of a society's health when seen in environmental terms. According to Robert Repetto of WRI (World Resources Institute), Washington, D.C., a country may exhaust its mineral resources, cut down its forests, pollute its aquifers, and hunt its wildlife to extinction, but its GDP would not be affected by the loss of these assets. Repetto is an ardent advocate of a greener GDP. His work in Indonesia in 1989 showed that annual GDP growth corrected for depreciation in timber, petroleum, and soil resources was 3% lower than the conventionally-calculated figure of 7.1% between 1971 and 1984.

INDEX OF SUSTAINABLE ECONOMIC WELFARE

Herman Daly criticizes the idea that a country's wealth can be measured just in terms of how much its citizens produce. He developed the Index of Sustainable Economic Welfare (ISEW). Although this takes GDP as its starting point, it adds the value of unpaid household work, and then subtracts the cost of pollution, as well as urbanization, road accidents, and advertising. But the ISEW has not yet become popular among policy makers and many economists because of inaccuracies in measuring some of its components. Despite such shortcomings, however, calls for a green GDP have now become louder.

The European Commission is now working on 60 environmental pressure indices intended to act as a measure of the health of various natural resources. It is also working with the UNEP (United Nations Environment Programme) and the OECD (Organization for Economic Cooperation and

Development) on so-called satellite accounts that attempt to put monetary values on different aspects of environmental degradation.

One reason for scepticism about a new green index is the lack of detailed knowledge of its potential components, such as accurate measure of water pollution, and climate change potential of greenhouse gases. The work on parallel indicators—which many countries are now carrying out—may help to address most of these issues. If we want to include environmental resources in GDP, we must have comprehensive information, e.g., detailed knowledge of each type of damage by each pollutant.

Most rich countries are not convinced about the utility of a new index, partly because they derive a smaller share of their earnings from natural resources than developing countries, and also because the parallel indicators are, in themselves, an adequate guide to environmental health.

Despite the setbacks, environmental and ecological economists continue to plead the case for a single index that integrates a measure of the wealth of a country's citizens and the health of its natural environment.

COSTANZA'S CALCULATIONS

The calculation by Costanza *et al.* (1997) of a monetary value for the world's ecosystem services and natural capital has become the subject of a hot controversy, even though the idea of valuing ecosystem services was not new. Earlier in 1997, Daily had edited a volume containing contributions that aimed to identify and characterize components of ecosystem value. But Costanza *et al.* (1997) tried to estimate the total value of all the world's ecosystem services. They arrived at the figure of $33 trillion per year, which exceeds the sum of the world's GNPs. Masood and Garwin (1998) compared several countries in respect of their GNPs (see Table 8.2).

Table 8.2 How green are some countries (after Masood and Garwin, 1998)

Country	GNP	Green NNP*	
		$ per capita as in 1993	Fall in GNP (%)
Japan	31,449	27,374	13.0
Norway	25,947	21,045	18.9
USA	24,716	21,865	11.5
Germany	23,494	20,844	11.3
South Korea	7681	7041	8.3
Indonesia	732	616	15.8
China	490	411	16.1
India	293	242	17.4

*Green NNP (net national product) is GNP minus depreciation of produced assets, depletion of forests and subsoil assets, and damage from carbon dioxide emissions.

The general consensus appears to be that a paper with serious technical flaws has still served a useful purpose by drawing attention to an important issue. The Costanza *et al.* (1997) paper described $33 trillion per year as a minimum estimate for the current economic value of 17 ecosystem services summed over 16 biomes ranging from the open ocean to urban centres.

Mainstream economists protested strongly. The figure of $33 trillion has been described as a serious underestimate of infinity. The biome-scale calculations attracted risk of ridicule from both scientists and economists.

For neoclassical economists, value can be measured in the context of only a specific exchange. It makes no sense to ask the 'value' of the world's ecosystem services. One can evaluate only small (or 'marginal') changes from current conditions. Real-world decisions are incremental: we may have to decide what it is worth to give up a hectare of beach, but we are never asked to give up all the beaches in the world.

One criticism has been that Costanza *et al.* (1997) took valuations of particular ecosystem services, made in specific parts of the world, and converted these to per hectare values for a particular biome. For example, they used values placed on soil formation in Colorado as the basis of a calculation for all the world's grasslands, assuming that all hectares of grassland are equivalent in the value of this service to local populations.

The critics pointed out that, because the value of a commodity increases as it becomes more scarce, one cannot just multiply the present value of a hectare of biome (even if there were a uniform value per hectare) by the number of hectares to get the total value. The last hectare to disappear will be much more valuable than the first!

Costanza *et al.* (1997) admit that what they did was imperfect in many ways, but believe that their number is better than no number at all.

According to Trudy Cameron, an environmental economist at the University of California (Los Angeles), the Costanza *et al.* (1997) paper was a recklessly heroic but useful attempt to do something that's futile.

ECONOMISTS' VIEW OF ENVIRONMENT

Through their zeal for market solutions, economists have contributed to some misunderstandings about how they think about the environment. Here are some prevalent myths about how economists think about the environment (see Fullerton and Stavins, 1998).

Universal Market

Economists generally believe that the market solves all problems. The popular and powerful theorem of welfare economics is that private markets are perfectly efficient on their own, with no interference from government, provided certain conditions are met. It means that no one needs to tell producers of goods and services what to sell to which consumers. Instead, self-interested producers and consumers meet in the market-place, engage in trade, and thereby achieve the greatest good for the greatest number. This maximum general welfare is what economists mean by the 'efficiency' of competitive markets. Economists in business schools love to identify markets where the necessary conditions are met (e.g., the stock market).

Other economists, e.g., those in public policy schools, view the theory differently. By clarifying the conditions under which markets are efficient, the theorem also points to the conditions under which they are not. Private markets are perfectly efficient only if there are no public goods, no externalities, no monopoly buyers or sellers, no increasing returns to scale, no taxes, no common property, and no other 'distortions' between the costs paid by buyers and the benefits received by sellers (see Fullerton and Stavins, 1998). Those conditions are restrictive and are hardly ever satisfied simultaneously in the real world.

Environmental economists are interested in pollution and other externalities, where some consequences of producing or consuming a good or service are external to the market (i.e., not considered by producers or consumers). With a negative externality, such as environmental pollution, the total social cost of production may exceed the value to consumers. If the market is left to itself, too many pollution-generating products are manufactured.

Natural resource economists are interested in common property, or open-access resources, where anyone can extract or harvest the resource freely and none knows the full cost of using the resource. Extractors consider only their own direct and immediate costs, not the costs to others of increased scarcity (user cost or scarcity rent). Consequently, the resource is depleted too quickly. In reality, the market by itself does not solve all problems. In the environmental realm, perfectly-functioning markets are the exception rather than the rule. Governments sometimes correct these market failures, e.g., by restricting pollutant emissions or limiting access to open-access resources, which can improve welfare and lead to greater efficiency (see Fullerton and Stavins, 1998).

Market Solutions

This myth says that economists always recommend a market solution to a market problem. They look for such instruments of public policy that can fix one market essentially by introducing another, allowing each to operate efficiently on its own. If pollution imposes large external costs, for instance, the government may create a market for rights to emit a limited amount of that pollutant. A market for tradable emission permits can work if there are many buyers and sellers, all are well-informed, and the other conditions of the first theorem (see discussion under Universal Market) are met. Here, the government's role is to enforce the rights and responsibilities of permit ownership, so that each unit of emissions is matched by the ownership of one emission permit. Then the market for the output will also work, because the producer must pay some price for each permit that reflects the social cost of the associated pollution. Likewise, producers are asked to pay a tax on their emissions that reflects the external social cost, for efficient pollution abatement at minimum aggregate abatement cost.

This tradable-permit approach is commendable but it is still a market, implying that the outcome will be efficient only if certain conditions are met. But these conditions are not always met. In those cases where the sale of permits is monopolized by a small number of buyers or sellers, where problems arise from inadequate information or significant transaction costs, and where the governments find it too costly to measure emissions, the permit market operates less than optimally. The environmental goal may still be met, but not at minimum cost.

There are many environmental problems that are not addressed appropriately by tradable-permit systems or other market-based policy instruments. One example is a hazardous air pollutant such as benzene that does not mix in the airshed and hence causes localized hot spots. Because a company can buy permits and increase local emissions, permit trading does not ensure that each location will meet a specific standard.

The lesson here is that no specific policy instrument is a panacea. Market instruments do not always provide the best solutions, and sometimes not even satisfactory ones (Fullerton and Stavins, 1998).

Market Prices

According to this myth, when non-market solutions are considered, economists still use only market prices to evaluate them. Regardless of the policy instrument chosen, the environmental goal of that policy must be identified. Economists try to identify the most efficient degree of control that provides the greatest net benefit, which means that both benefits and costs have to be evaluated. Economists like using market prices, whenever possible, to make such evaluations, because these prices reveal how members of society actually value the scarce amenities and resources under consideration. But this does mean that economists are concerned only with the financial value of things. The financial flows that make up the GNP represent only a fraction of all economic flows. The scope of economics encompasses the allocation and use of all scarce resources. For instance, the economic value of the human health damages of environmental pollution is much greater than the sum of health care costs and lost productivity, as it includes pain and suffering.

To take another example, the economic value of a tropical rain forest is not limited to its monetary value as a storehouse of future pharmaceutical products or as a location for ecotourism. That use value is but a small fraction of the properly-defined economic valuation. Economists have long recognized the importance of non-use value of environmental amenities such as wilderness areas and endangered species. The public nature of these goods makes it very difficult to quantify these values empirically, as we cannot use market prices! Benefit-cost analysis of environmental policies, by definition, cannot rely exclusively on market prices (Arrow *et al.*, 1996).

Economists insist on converting all these disparate values into monetary terms because a common unit of measure is needed to add them up.

Efficiency

This myth means that economic analyses are concerned solely with efficiency rather than distribution. No doubt there are many economists who give greater attention to measures of aggregate social welfare than to those of the distribution of the benefits and costs of policies among members of society, but this is because an improvement in economic efficiency can be determined by the simple and unambiguous criterion of an increase in total net benefits. What constitutes an improvement in distributional equity, on the other hand, is hotly debated. Nevertheless, many economists do analyze distributional issues thoroughly. The more difficult problem is how to appropriately unify efficiency and distributional issues.

According to Fullerton and Stavins (1998), economists do not necessarily believe that the market solves all problems. Indeed, many of them are analyzing market failures such as environmental pollution in which *laissez-faire* policy leads to social inefficiency. When economists identify market problems, they first consider the feasibility of market solutions because of their potential cost-effectiveness, but market-based approaches to environmental protection are no panacea. When market or non-market solutions to environmental problems are being assessed, economists do not limit their analysis to financial considerations but use money only as a unit of measurement in the absence of a better unit.

ECONOMICS, ECOLOGY, AND BIODIVERSITY

In an economic perspective, while the private benefits of biodiversity loss are captured in market prices, many of the associated costs are not. Markets for foods and fibres drive specialization in agriculture and forestry. But the same markets do not reflect or signal the costs of land conversion and agricultural specialization to society in general. As these costs are deemed to be external to the market, they tend to be ignored by decision makers on the basis of market prices.

To give due attention to the external costs of biodiversity loss, governments need to look beyond market prices. The true value of biodiversity reflects not just its direct or indirect value but also the value it has independent of use. This includes, for instance, the value placed on its availability to others whether now or in the future. It includes option value (the value of the option to use resources in the future), quasi-option value (the future value of the information contained by a resource), bequest value (the value of a bequest to future generations), and, sometimes, existence value (the value of knowing that something exists) (Perrings, 1995, 1995a). Until recently, most focus on the value of biodiversity has been either on the direct use value of particular organisms, or on the option, quasi-option, and bequest value of the gene pool. There is now indication of some shift in emphasis. The main value of biodiversity, as distinct from the value of individual biological resources, may well be indirect and derived from the role of a combination of species in supporting specific ecological services, such as watershed protection, waste assimilation, microclimatic stabilization, and carbon storage. Biodiversity in tropical forests has usually been valued in terms of timber, medicinal plants, hunting, fishing, recreation, and tourism. It is now being valued through its role in habitat provision, soil conservation, soil productivity, water supply, water storage, and flood control (Perrings, 1995a). It is being realized that most such ecosystem services are mediated by particular combinations of species. The set of species that supports ecological processes under one set of environmental conditions may differ from the set of species that supports the same processes under a different set of conditions. The mix of species in an ecosystem enables the system both to provide a flow of ecosystem services under given environmental conditions and to maintain that flow if environmental conditions change (Perrings, 1995a).

ECONOMICS AND MINING

The finiteness and non-renewable nature of mineral deposits warrant a careful long-term policy for extracting minerals from mines. But, unfortunately, mineral deposits are usually exploited with the profit motive, the efforts being to extract as much as possible from mines at as low a cost as possible. For businessmen, the maximization of profits is the guiding principle. If all deposits of useful minerals were treated as per the principle of profit maximization, then the inevitable consequence would be the irreparable devastation of the natural resources of the earth, which would threaten the continued existence of mankind.

Wahl (1983) advocated the pursuit of the following two goals in the context of mining:

(1) The particular mining possibilities of negative rationalization should be made more transparent and this positive measure of business economy should be distinguished clearly from overmining (coyoting). This is done on the basis of a discussion of the economic profit potential of deposits from the point of view of business economy and the possible use of this potential (Fettweis, 1995).

(2) The economic principle should be brought within the larger framework of the rational principle which applies additionally to areas and connections not quantifiable in terms of money. Mines and their deposits need to be evaluated from the viewpoint of national economics and

thus of the economy as a whole.

The mineral ores have the same place in the primary production of mining that raw materials, basic materials, or primary products have in production, in finishing, or manufacturing. Correspondingly important for every individual mine, therefore, is the factor quality of the particular mineral deposit. This factor quality means the production process and the product being manufactured. In the case of mineral deposits, they are the geologically-determined features or the geomining conditions of the deposit which are significant for the costs and revenues of mining enterprises. It is practical to classify these evaluation-relevant features according to the substance quality, extractability, and quantity of the mineral deposit. These features are known to vary considerably from deposit to deposit and also within one and the same deposit.

In contrast to the raw materials for many manufacturing industries, the feedstock of mining consists of the unalterable and limited supply from nature. This means that most mines constantly have to select their minable reserves among the geologically-available parts when planning extraction, and as a function of this selection not only the economic results but the expected working life of the enterprise tend to change.

The extractability of the deposit changes with the reserve variation, i.e., the sum of all geological features which, given a certain size of the mine, influences the extraction costs per unit. These features include, for example, thickness and microtectonics.

The national importance of mines, or the benefit they bring for the total economy of a country, does not equal the sum of the business economic results of the individual mining enterprises.

For the national economic evaluation of mines, an independent calculus is necessary. We need to consider all the effects relevant to the social benefits of the national economy, though methodologically-precise calculations of such a kind are extremely difficult. This applies especially to the nonmonetary sphere. The most important tool for national economic calculations with monetary values is cost-benefit analysis. Evaluating the benefits of mining which cannot be expressed in monetary terms is very difficult but can be partially achieved by using dimensionless quantities. In the cost-benefit analysis, the benefit is recorded as dimensionless degrees of goal accomplishment; in contrast, the value analysis may work for expenses and benefits by assigning certain arbitrary points.

ENVIRONMENT, ECONOMICS, AND TRADE

The relationship between trade and the environment involves two crucial issues: the trade implications of domestic and international environmental measures, and the environmental effects of trade liberalization.

Whereas much progress has occurred in identifying potential trade effects of environmental policies, much less progress is being made in identifying potential environmental impacts of trade, largely because of the great complexity of the environmental assessment of trade liberalization and other economy-wide policies. It is particularly difficult to identify environmental impacts at the micro-, sectoral, and country level associated with macroeconomic reforms. Also, there are serious difficulties in delineating dynamic direct and indirect economic effects of liberalization, and relating these to likely environmental impacts. Environmental considerations associated with trade liberalization include effects of scale, technology, and structural and product composition effects (Vaughan, 1995).

It is very important to identify and reform underlying market, pricing or policy failures which contribute to ecological destruction. A guiding assumption of sustainable development is the need to integrate environmental factors into core economic policies.

The need for economics-ecology integration is particularly strong in the face of accelerating, unprecedented ecological degradation of planetary dimensions. Symptoms are as broad and startling as record high levels of ozone layer depletion; massive loss of biodiversity; continued proliferation of hazardous wastes and toxic chemicals; sharp jumps in urban air and water pollution in several developing nations; collapse of fisheries; decline in environmental quality in the oceans; and land degradation and desertification (Vaughan, 1995). These acute environmental problems have caused a shift of focus in the environmental agenda, and current policies are addressing not only the symptoms of ecological degradation, but also the underlying economic causes.

The general aim of environmental assessments is to (1) establish more quantifiable cause-effect links between economic activity and ecological quality; (2) identify where environmental policies—such as command and control regulations coupled with economic instruments—ought to be put in place; and (3) identify where economic policies themselves need to be adjusted, reformed or redesigned to take account of environmental carrying capacities (Vaughan, 1995).

One central assumption of economic reforms relates to the economic benefits of removing non-market public sector intervention such as energy use and agricultural subsidies. Once eliminated, resources are more efficiently allocated, according to market signals. Most environmental gains resulting from economic reform are usually incidental, rather than by design.

Trade liberalization has an important bearing on economy-ecology links but it is often being introduced in parallel with other, equally dramatic economy-wide reforms which collectively (including economic structural reforms, trade liberalization, and price stabilization policies) tend to transform the interplay between economic and environmental policies. One example: changes in pricing structures associated with liberalization may alter pricing incentives or disincentives regarding the use of natural resources, or how pollution is regulated. Liberalization reforms often increase environmental problems, at least in the short term, because of complex indirect effects.

There is evidence that transitional periods in economy-wide reform are usually associated with very painful social and environmental impacts. Structural adjustment and price stabilization policies, for example, often generate high rates of unemployment, pronounced income distribution effects, and increase in the cost of credit. The environmental effects of economy-wide reforms can precipitate significant environmental impacts, including, for example, increased pressure on marginal lands (Vaughan, 1995).

TRADE AND SUSTAINABILITY

The major objective of environmental policy in many countries now is sustainable development. Sustainable development implies two subobjectives, viz., (1) the quality of the environment must be sustained, and (2) the economy must continue to develop. Here, environment includes the ecological processes and natural resources on which life depends, and economy broadly includes all human activities. Improving the linkages between the environment and the economy contributes directly to sustainable development. The process of improving these linkages is termed as policy integration. Although there is much uncertainty concerning both environmental and economic futures, the precautionary principle implies that the lack of total scientific certainty should not be used as a reason to postpone policy action that will sustain critical environmental values in the long term (OECD, 1996).

In the context of environment-economy integration, considerable progress is being made toward better integration in the following areas in European countries. Some tax regimes have been reformed along environmental lines; some environmentally-harmful subsidies have been reduced; better data and analytical tools are becoming available; institutions are being reformed to be more sensitive to environmental needs; and public awareness of market and policy intervention failures has grown. Further, significant structural changes in the underlying environment-economy relationship have occurred in a few advanced countries. Some have succeeded in decoupling certain elements of environmental degradation from economic development, especially in the energy sector, where energy intensities have declined steadily since 1974, despite significant decreases in real energy prices since 1984. However, a few less developed European countries have started experiencing rising energy dependence, as their own economic development accelerates (see OECD, 1996, 1996a).

The perspectives on environment-economy integration may be outlined as follows:

(1) Geographic, the extent to which local, national, regional, and international environmental or economic policies support each other.

(2) Economic sectors, the extent to which sectoral economic policies such as agriculture, transport, energy, industry, and trade take cognizance of environmental concerns.

(3) Economic actors, the degree to which individual consumers, firms or lobby groups realize that environment and economic policy goals are linked.

(4) Environmental resources, the extent to which policies affecting individual environmental resources such as air, water, land, and wildlife are consistent with each other (ecosystem approach).

(5) Policy instruments, the degree to which different environmental regulations, economic incentives, and technology development for education produce consistent and complementary results.

(6) Policy level, the extent to which macro- and micropolicies mutually support each other within environmental and economic policies.

(7) Processes, the degree to which industrial manufacturing processes reflect environmental needs (integrated pollution control concept or life cycle management).

(8) Temporal, the degree to which environmental and economic policies are integrated over time (short- vs. long-term; present vs. future generations).

A small success has been achieved in quantifying the economic impacts of environmental externalities but several difficulties exist for assessing global or regional externalities. Estimates of environmental damage have not yet entered the mainstream of economic policy-making. Stronger methodologies are therefore needed for dealing with environmental externalities.

In Europe, current environmental policy is mostly the prevention and control of pollution activities, the basic foundation being the polluter pays principle (PPP). The PPP was originally designed as an economic principle but it has now evolved into an environment and economy principle over time. Although it has become a de facto tool for policy integration, it is still a tool which focuses on the pollution prevention and control aspect of the problem (see Table 8.3).

DEGRADATION THROUGH OVERUSE

It is well-known that the environment can become degraded through the overuse (or gradual deterioration) of the natural resource stocks, including biodiversity, on which economic activity depends. This means that environmental and economic policies will never be fully integrated until both pollution control and natural resource management/biodiversity perspectives enter decision-making. Currently, environmental policies in most countries do not place sufficient emphasis on the resource management objective, and some redressal of this imbalance is urgently warranted. Tax policy is the most popular route for applying economic instruments but there is also increasing awareness of the advantages of other types of economic instrument, such as tradable permits and deposit refund systems. Economic instruments are being designed that are more

Table 8.3 Evolution of PPP

Year(s)	Remark(s)
1972, 1974	Adoption of PPP by many European countries, but aimed only at non-subsidization of those pollution control costs which are legally enforceable by virtue of government rules
1975, 1978	Extension of PPP to include allocation of government's administrative costs to polluters
1989	Extension of PPP to include area of accidental pollution (not just chronic pollution as was originally the case) Henceforth, neither the risk nor the cost of preventing/controlling accidental pollution to be borne by public authorities
1990	Recognition of PPP as a general principle of environmental law
1991–92	Appreciation in Europe that not only pollution prevention and control costs, but also pollution damage costs should be borne by the polluter Economic instruments are formally recognized as a key vehicle for achieving internalization of these costs Inclusion of PPP in Maastricht Treaty

environmentally-effective, so also more cost-effective environmental regulations. The end objective should be the generation of more cost-effective and more environmentally-effective combinations of policy instruments (OECD, 1996).

GLOBALIZATION

Recent agreements to reduce trade barriers (e.g., European Single Market, Uruguay Round) are part of a trend towards the globalization of economic activity. This is expected to have four key economic and trade impacts, namely, (1) increased world trade, (2) increased foreign investment, (3) increased international competition, and (4) increased demand for transport services. Each of these changes may generate new environmental impacts and/or opportunities. Increased world trade can positively impact the environment by improving the efficient allocation of resources, by promoting economic growth, and by increasing general welfare, provided that there are suitable environmental safeguards. Increased trade can make environmentally-sound products or technologies more readily available (product effects); in promoting economic development, it can generate the new economic resources needed to pay for an improved environment (scale effects); it can minimize market or policy failure (structural effects); and it can enhance the efficiency of existing regulatory arrangements (regulatory effects).

Unfortunately, increased trade can simultaneously degrade the environment if increased economic activity leads to higher levels of environmental externalities (scale effects); if externalities lead to environmentally-damaging structural shifts in economic activity (e.g., changes); or if hazardous products become more easily available (product effects).

Increased foreign investment can, depending on particular circumstances, generate either positive or negative environmental impacts. If new foreign investment increases economic activity, it may again degrade the environment in the absence of effective environmental controls. On the other hand, the transnational companies most likely to be making these investments are also becoming more and more conscious of their 'green' image. Furthermore, it is economically sensible for these companies to adhere to one high environmental standard in all their operations worldwide. And finally, there is no evidence that industrial relocation to 'pollution havens' is a generalized problem. All these factors will tend to reduce the adverse environmental effects expected from increased foreign investments.

On the one hand, stricter environmental policies have not had much long-term adverse impact on either micro- or macroeconomic competitiveness; the large business sector usually overstates the negative impact of environmental policies on its economic position. On the other hand, concerns about reductions in short term and/or local competitiveness form an integral part of the political debate about environmental policies, hence this is certainly an area that warrants further assessment.

The net effect of increased transport on the global environment is likely to be negative especially if mobility expands in the developing countries to the same levels as prevalent in the industrialized countries (Long, 1995).

Although the specific environmental effects of a more open global trading system will vary from country to country, these effects are likely to be positive in the aggregate, provided that appropriate environmental safeguards are implemented hand in hand with the trade liberalization process.

No doubt there has been some progress in understanding the economic effects of environmental subsidies but very little is known about the environmental effects of economic subsidies. Efforts are now underway to obtain transparent and comparable information about public assistance to several economic sectors, but full comparability of this information across countries, across sectors, and over time is a very distant goal.

Environmental policies generally exert a negative effect on employment because of reduced competitiveness, project delays or cancellations, and industrial relocation ('pollution havens'). The public tends to view environmental policies as 'job killers'. However, available evidence does not support the thesis that environmental policies in European countries exert a net negative effect on total employment. On the contrary, although this linkage is probably weak, it is actually positive. The short-term employment effects of some environmental policies may, however, be significant for some specific industries, sectors, or regions (Repetto, 1994).

Regular reporting of information concerning the state of the environment, as well as periodical assessments of environmental, energy, and agriculture policies help focus attention on the environment-economy integration problem. There has been a far longer tradition of interpreting basic economic data for use in policy-making than there is for interpreting similar environmental data. Consequently, serious weaknesses remain in the quality of indicators that link the environment to the economy. More integrated indicators which link environmental and economic activities directly to the goal of sustainable development need to be developed. Environmental tools are usually based on physical parameters whereas economic tools are normally based on monetary values. This difference hinders their further integration. Economic policy tools have found various ways of comparing their results across both space and time (e.g., price indices and discount rates). No similar methods have yet been developed in the field of environment (see OECD, 1993, 1993a, b, c, 1996).

FUTURE DIRECTIONS

Some plausible future directions in addressing the issues we have been discussing are as follows:

(1) Intensification of efforts is needed to promote research on the environmental effects of sectoral economic activities, with special emphasis on standardizing damage estimation methodologies.

(2) Resource management and biodiversity objectives need to be better integrated into the environment-economy planning alongside pollution prevention and control objectives.

(3) Competitiveness issues form the core of environment-economy policy linkages. There is a need for more research into these effects along the following lines:

(a) A broader understanding needs to be developed of how competitiveness is actually affected by environmental policies.

(b) Better ways have to be found to mitigate or compensate the worst of these effects. Mitigation may involve some form of harmonized action. Compensation may involve revenue-sharing.

(c) As the beneficial effects of environmental policies on competitiveness are often underemphasized in policy debates, special efforts need to be made to ensure that these effects are both understood and publicized.

(4) Special efforts should be made to improve understanding of the best combinations of economic instruments and other approaches, as well as of the conditions under which each would be most appropriate.

(5) More creative use of the tax system for environmental purposes is another integration opportunity. Ways have to be found to increase public acceptability of these reforms.

(6) It appears that short-term, microeconomic aspects of the environment-employment interface may be more important than the long-term, macroeconomic aspects. A better understanding of the nature and size of these microeconomic effects is needed.

(7) Efforts should be made to maximize the positive environmental effects (and to minimize the negative effects) of a more globalized economy. The environmental effects of trade liberalization need to be better understood. Sectoral studies (agriculture, energy, industry, and transportation) would be the main focus for this work. In view of the increasing importance of the service sectors, special efforts should be made to understand the environmental effects of trade liberalization in this sector.

(8) More integrated indicators (i.e., indicators capable of describing environmental and economic trends at various levels of the sustainable development hierarchy) should be developed. Three priorities are the following:

(a) Development of better vertical linkages between analytical tools at the micro- and macroeconomic levels. Relationships between individual environmental indicators (microeconomic level) and environmental/economic accounts (macroeconomic level) need strengthening.

(b) Development of better horizontal linkages between environmental and economic tools across sectors, regions, or countries.

(c) The time dimension of environmental indicators deserves greater emphasis because it reflects the results of previous management decisions, and therefore increases government accountability. Reliable time-series should be developed for the most important indicators of environment-economy performance.

ECONOMIC INSTRUMENTS AND ENVIRONMENTAL PROTECTION

Economic instruments are being increasingly used in the achievement of environmental protection. They are defined as instruments that affect costs and benefits of alternative actions open to economic agents, with the effect of influencing behaviour in a way that is favourable to the environment (OECD, 1991). One aim of such instruments is to ensure that appropriate pricing will promote the efficient use of a particular resource. Currently, these instruments have been mainly used in the OECD countries (the US, Sweden, Norway, and Denmark having highest usage). One criticism has been that they are used mainly to generate revenue for governments rather than for any real environmental protection. This aspect is particularly significant in some developing countries depending on what the value of the revenue to be collected is or whether the economic instru-

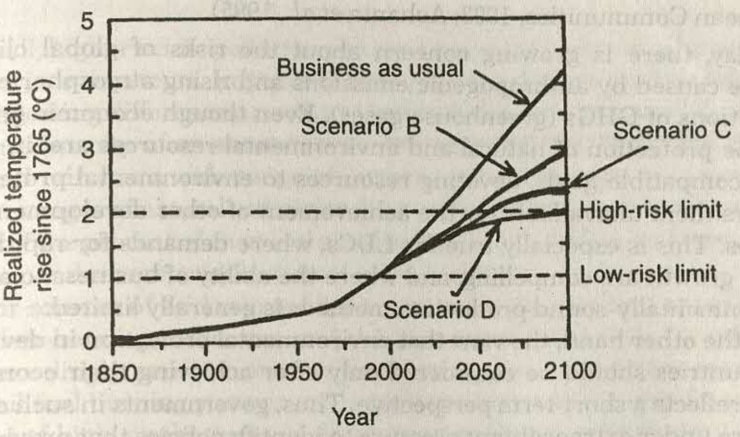

Fig. 8.3 Simulations of increase in global mean temperature during 1850–1990 on the basis of observed increases in greenhouse gases and predictions of rise between 1990 and 2100 resulting from IPCC (Intergovernmental Panel on Climate Change) scenario B, C, and D emissions, with business-as-usual case for comparison.

ment is revenue-neutral (see Achanta *et al.*, 1995).

Developing countries accounted for nearly 30% of global energy demand in 1990, and this share is likely to rise to about 70% by the year 2050. IPCC (1990, 1994) estimated that the share of primary energy demand of LDCs (least developed countries), under a high emission (business-as-usual, i.e., non-interventionist) scenario, can rise from 22% (in 1985) to over 60% in 2100. Further, many recent projections (see Fig. 8.3) suggest that much of this growth in global energy demand will continue to be based on fossil fuels under a business-as-usual scenario. This may well aggravate both resource depletion and environmental pollution despite improved energy production and adoption of cleaner combustion technologies. The selection of a growth trajectory for an LDC, aimed at containment of energy demand growth and environmental degradation, would depend on the following variables and considerations:

(1) depletion of low-cost resources, supply disruption, or the nature and gravity of possible environmental constraints;

(2) economic, political, social, and behavioural changes;

(3) whether more centralized or more dispersed solutions are sought in the energy sector;

(4) whether existing institutional and administrative mechanisms prove to be sufficiently flexible and adaptive; and

(5) numerous technological changes and interactions within and outside the energy sector in such diverse fields as biotechnology, electronics, materials, photovoltaics, and telecommunications (Commission of the

European Communities, 1993; Achanta *et al.*, 1995).

Today, there is growing concern about the risks of global climate change caused by anthropogenic emissions and rising atmospheric concentrations of GHGs (greenhouse gases). Even though economic growth and the protection of natural and environmental resources are, in principle, compatible goals, devoting resources to environmental protection renders them unavailable for the achievement of other development objectives. This is especially true for LDCs, where demands for rapid economic growth are compelling, and where the ability of business to afford environmentally-sound production methods is generally limited.

On the other hand, the view that environmental protection in developing countries should be considered only after achieving their economic goals, reflects a short-term perspective. Thus, governments in such countries are under extraordinary pressure to identify policies that provide an acceptable level of environmental protection while minimizing cost and the degree to which they act as disincentives to economic progress. In the light of this trade-off, the identification of suitable policies requires an understanding of the nature of environmental problems, the economic impacts of alternative environmental policies, the institutional conditions, and the societal arrangements required for policies to be implemented effectively (see Achanta *et al.*, 1995).

Two important environmental problems being addressed in part through the use of economic instruments are acid rain and global warming. In these cases, the use of economic instruments has remained limited to the national and regional level.

ACID RAIN PROBLEMS

The term acid rain was coined a century ago by a British chemist to refer to significant changes in the chemical composition of precipitation caused by air pollution. There is a normal amount of acidity in rainfall, largely from the absorption of carbon dioxide and other natural background sources of acidity. It has been seen that acidity in precipitation can be as much as ten times higher than normal background levels because of airborne sulphur dioxide and nitrogen oxides. Globally, every year, an estimated 70 million tons of sulphur dioxide are released into the atmosphere, together with an estimated 27 million tons of nitrogen in the form of nitrogen oxides.

One of the many environmental consequences of increased levels of sulphur and nitrogen pollution appears as increased acidity of rainfall (see Kumar and Kumar, 1997). Normal precipitation in most areas of the world is slightly acidic, with a pH of approximately 5.6. By contrast, rainfall with a pH of 4.0 and 4.5 in the eastern US occurs frequently, while cloud droplets have had pH levels as low as 2.6 in New York. One consequence of significant changes in acidity has been seen in over 200 lakes of the Adirondack Mountains of New York State, where fish disappeared as early as 1982.

Overall, higher acidic pollution can create systemic, abrupt, and severe changes in ecosystems. Impacts of acid rain are diverse at the regional level, reflecting differences in soil and bedrock characteristics which influence the capacity of an ecosystem to neutralize acidity. Generally, however, acid rain has a wide range of impacts, including damage to vegetation by changes of natural soil cycles, lowering of soil nutrient levels, acceleration of the process of chemical weathering of soils, decline in forest productivity, and severe acidification of lakes and rivers.

Major sources of acid rain are concentrated in the smelting or refining of sulphur-bearing metal ores and the burning of fossil fuels for energy use. Accordingly, emission sources from ore smelters and power-generating fossil fuel burning stations are largely concentrated in specific areas. The use of high smokestacks to disperse air pollution contributes to the long-range, transboundary movement of acid rain.

Due to the transboundary nature of the acid rain problem between Canada and the US, officials are contemplating a transboundary sulphur oxides emission trading system which would allow an expansion of the market for permits and savings associated with reduction of acid rain. Recent bilateral schemes regulating acid rain between Canada and the US have included such economic instruments as tradable emission schemes. At the international level, the 1979 Convention on Long-Range Transboundary Air Pollution has been amended with increasingly strict protocols governing allowable emissions of sulphur dioxide.

In Europe, emission ceilings ranging from 30% to 87% of 1980 emission levels have been set for various countries covering a flexible schedule for the years 2000, 2005, and 2010. Governments have agreed to reduce sulphur deposition in Europe by 60% under this schedule; and new requirements are established for certain stationary combustion sources and for the sulphur content of gas oils.

GLOBAL WARMING

Increases in the atmospheric concentrations of GHGs, particularly carbon dioxide, are thought to lead to irreversible climate change. The earth's mean surface temperature may increase by 3°C by the end of the twenty-first century, with likely impacts on agriculture, forestry, natural terrestrial ecosystems, hydrology, water resources, oceans, and coastal zones.

The IPCC in 1990 recommended a 60% reduction in carbon dioxide emissions in order for atmospheric equilibrium to be reached. The developed countries were asked to adopt national policies aimed at returning GHG emissions to 1990 levels by the year 2000, but there are no specific commitments of emission limits specified for the developing countries. Some nations within the European Community have already started applying national carbon and other related taxes. One major objective: the stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Further, policies and measures to combat climate change should be cost-effective so as to ensure global benefits at the lowest possible cost. Measures taken to combat climate change, including unilateral ones, should not constitute means of arbitrary/unjustifiable discrimination or a disguised restriction on international trade. Other goals pertaining to trade relate to the adverse effects of implementation of response measures on those LDCs which are vulnerable as a consequence of their high dependence on income generated from the production, processing, and export, and/or on consumption of fossil fuels and associated energy-intensive products.

SUBSIDIES

The environmental effects of sectoral economic subsidies are incompletely known. What exactly is a subsidy? Efforts to understand both the nature and the size of subsidies must first address the conceptual problem of defining precisely what a subsidy is. Is a payment a subsidy, an investment, or a fee for a service (i.e., public good)? What part of the payment should be allocated to each beneficiary, in a cost accounting sense? One possible way of classifying subsidies is according to their objective. From the perspective of the environment, two types of subsidies are of most interest, viz., (1) subsidies whose objective is economic, but which compete with environmental goals incidentally (e.g., subsidies to promote the supply of energy, agriculture, manufactured goods, and transport); and (2) subsidies whose objective is environmental from the start (e.g., subsidies for environmental protection equipment). Another way to classify subsidies is according to their form. In this case, subsidies could be viewed as being either direct (e.g., through prices and budgetary transfers) or indirect (e.g., through the tax system, concessions from legal liabilities, low interest loans, and cross subsidies). Subsidies may also be implicit, in that some of the true costs of production and consumption are borne by others. A good example here is environmental costs which are not reflected in market prices.

Table 8.4 lists certain efficiency implications of various kinds of environmental subsidies.

Subsidies are sometimes regarded as "taxes in reverse". Much more is known about the relationship between the environment and tax policies than about that between the environment and subsidy policies. Future work should emphasize three priorities:

(1) Defining and understanding the breadth of existing subsidy activities, in an environmental perspective.

(2) Modelling the impacts of existing subsidy policies on environmental parameters, including the potential impacts of removing these subsidies across countries, across economic sectors, and over time.

(3) Understanding the conditions under which payments for envi-

Table 8.4 Efficiency implications of some types of environmental subsidy (after OECD, 1995)

Subsidy	Efficiency distortion	Remark(s)
For *ex post* clean up of past environmental problems	No	Inappropriate to charge current operations with past sins—some risk however that too much clean up will occur since it is being publicly financed
For developing or transitional economies	No	Subsidies should be regarded as part of foreign aid but ought to be distributed through international programmes
For environmental research and development and for 'clean' technologies	No	A public good is being created, at least, until a proprietary asset has evolved, at which time the subsidy should be withdrawn
To 'upstream' inputs to the production process, or to natural resource sectors	Probable	As agriculture and natural resource sectors produce much of today's pollution in several countries, any long-term relief offered to these activities may generate both environmental and economic distortions
To improve environmental standards (or to enforce high standards)	Perhaps	Failure to enforce standards violates PPP; however, different standards in different countries are fully consistent with both economic and environmental goals
Based on environmental performance	No	However, the subsequent subsidy might undermine the original environmental improvement; in the long term, other distortions may also occur (e.g., slower adjustment to new technologies and too many firms being attracted to industry)
For pollution abatement	Yes	Direct distortion

ronmental services may be considered to be economically efficient (i.e., in supplying public goods). This is particularly relevant to the agriculture and transport sectors.

GREEN MARKETS

One great accomplishment of the American people during the past two decades has been to turn the tide of environmental destruction. The air and water in the US today is markedly cleaner in respect of most noxious and easily regulated pollutants. Chertow and Esty (1997) brought together the thinking of several experts on how the next generation of environmental policies can yield greater benefits while costing less. Firms can meet ambitious goals while choosing the most efficient methods. Effluent taxes can make polluters account for ('internalize') the environmental costs of their actions. Through market forces, millions of decentralized decisions can add up to a vibrant economy and a clean environment. This contrasts with the first generation of environmental policy which was marked by governmental command and control. Government regulators specified technologies and processes which often got the job done but stifled innovation and raised the costs of compliance.

A holistic, ecological approach to environmental policy is necessary to ensure that diverse environmental and economic goals are met at the same time. In the past, problems were often solved one at the expense of another. For example, averting local respiratory problems as well as acid rain by scrubbing SO_2 from smokestacks made power plants less efficient, causing them to spew more CO_2, the chief cause of global warming.

Market-based mechanisms are increasingly common, as are many forms of efficient voluntary regulation. Less common, but now catching up are policy and planning on the basis of whole ecosystems rather than individual species, pollutants, or sectors.

Market methods hold a promise of overcoming the political obstacles. Private capital flows now far exceed official international development assistance. Thus, environmental protection will increasingly depend on how private money is invested; environmental standards for investments and other techniques can leverage environmental benefits as the economy globalizes. Small bubbles within which polluters trade pollution rights may soon evolve to a full-fledged highly cost-effective emission trading system. It is being realized that there is an urgent need for much better data on the sources and consequences of environmental stresses. Though a rational setting of priorities is essential, it will be possible only when sufficient data are available.

The field of industrial ecology, which deals with analysis of where materials and energy flow throughout the economy over the full life cycle of products and services, is now gaining momentum. Such analysis is the key to a holistic ecological rather than fragmented approach to environmental policy. Fragmented approaches, although imperfect, have been used in the past partly because they are less knowledge-intensive, easier to visualize, and often effective. The holistic approach requires choices between contending values, and how those political conflicts can be resolved in democratic politics is often not discussed.

MARKETING OF AGRICULTURAL PRODUCTS

In the Third World, periodic markets play an important role in the local economy and social life of villages. These markets have a central function in the process of collection and distribution of goods and in the diffusion of information. Periodic markets in fact act as a spatial and temporal system that is quite adaptable to changes in socio-economic conditions and requirements. This is because they have a major role in the distribution of local foodstuffs. The prevailing option about this distributional function has so far been regarded as the collection of local foodstuffs for wholesale buying.

The itinerant trader expands his business area and hence his turnover by following the rotation cycle of periodic markets. In fact, both periodic markets and control places are focal points in space and time where supply and demand of different goods are satisfied in the collecting and distributing process.

Markets can be classified into urban and rural, or wholesale and retail markets. They constitute a continuum from the most elementary to the most complicated economies, periodic markets being a part of the most elementary whereas retail shops are part of the most complicated economy. Periodic markets as a type are those that are located between a completely underdeveloped house economy and a totally developed traffic economy. Population density, market production, purchasing power, and accessibility are indicators of the different tiers of market development (Braun *et al.*, 1998). Involvement in market production may even stimulate the function of periodic markets as food suppliers.

By and large most periodic markets in developing countries are collecting centres for agricultural products. Not necessarily linked to settlements, they are the starting point of the flow of foodstuffs from food-surplus areas to food-deficit ones. With an increase of the purchasing power of the local population, the demand for goods other than those locally produced adds to the task of distribution. Therefore, the enlarged function of periodic markets as collecting or distributing centres for various products is an indicator of the economic activity and efficiency of a region. The range of products and services offered indicates the importance of markets as supply centres (Braun *et al.*, 1998).

One important aspect of the marketing behaviour of rural traders may be observed on the daily wholesale markets. Some of these suppliers run their business at two levels. They themselves, family members, or agents, attend various periodic markets on different tiers of centrality. Thus, they can attend wholesale, daily, and periodic markets within a traditional market week. Also, the number of market operations in periodic markets for agricultural products, and the quantity supplied in a market per week, are inversely related to the percentage of mobile traders offering their goods (see Braun *et al.*, 1998).

In some localities, the production of basic foodstuffs is below the level of subsistence. Here, the chief function of rural markets is the distribution of agricultural products brought from elsewhere to the rural populations. It is now emerging that contrary to popular belief, periodic markets cannot be taken as simple indicators of underdevelopment (Braun *et al.*, 1998).

9

Social Issues and Sustainability

INTRODUCTION

A few specific issues of particular relevance to the social dimensions of environment and sustainable development are as now outlined.

Land Tenure

Land tenure is obviously important for sustainable development. The lack of stable and clearly-defined rights to land and resources often contributes to deforestation, soil erosion, and other types of resource degradation. People who do not own the land they farm, and are not sure that they will be working the same land next year, have little incentive to invest labour or curtail production this year in order to preserve the soil for future crops. Pastoralists whose traditional tenure rights have been infringed upon are no longer able to practise the extensive grazing practices which are necessary to make their way of life sustainable. Legislation which clarifies land rights, conferring security of land tenure on land users, can help alleviate environmental pressures. However, land privatization can have adverse effects. It appears that areas which have the potential to benefit the most from land legislation and reform are those in which the traditional tenure systems have been uprooted by outside interventions.

Population Dynamics

Population growth is the most important exacerbating factor in environmental degradation worldwide. The rising levels of consumption required by the growing populations demanding higher standards of living will inevitably put pressure on the natural resource base. Rates of resource extraction are determined by the population size, level of consumption, and the efficiency of existing technologies for resource use. Globally, if the efficiency of resource use is not improved, unchecked population growth is sure to lead to the degradation of resources.

In many production systems, population pressure affecting the resource base is a major factor in environmental decline: if rising numbers of people obtain their living from the natural resources without changing their production techniques, they are forced to cultivate steep slopes, reduce fallow periods or overgraze grasslands. However, local population density may not always be directly related to environmental decline: the consumption of resources, rather than population size as such, is the direct cause of degradation, and methods and levels of resource extraction are not always correlated with local population densities.

The interrelationships between population growth rates, environment, and factors which affect both the environment and population are often very complex (see Fig. 9.1). Social dynamics which work to keep population growth high can also have adverse effects on the environment.

Deforestation

Deforestation constitutes a special case of environmental degradation. Tropical deforestation has aroused a great deal of concern.

Land tenure institutions have a major impact on both the exploitation of forest resources and the social consequences of deforestation. Agricultural tenure which is insecure, inequitable or autocratic leads peasants to invade forestlands. Forest tenure systems must also be secure, equitable, and participatory, or incentives for sustainable forest management will not exist, and forest resources are likely to be destroyed. Land reform is therefore often a prerequisite for addressing problems of deforestation. Successful land reform must have a solid social and political base, and requires peasant mobilization and organization.

Both policy failure and market failure may be responsible for deforestation. Politics and economics are interconnected.

Urban Environment

In rural areas, environmental degradation is often directly associated with declining livelihood opportunities, but in urban areas this association may be reversed, i.e., economic opportunities are often increased with the presence of polluting industries. Waste disposal can support some poor people who live from picking through and recycling garbage. The major adverse impacts of urban environmental problems are felt not on people's livelihood directly, but rather on their health. Infectious diseases become more prevalent in crowded areas as do respiratory disorders while chemical and industrial hazards threaten large groups of people.

There is a tendency for urban environmental problems to affect the poor most severely, as poor populations are usually more concentrated, with less access to piped water and sanitation facilities.

SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES

Introducing sustainable management into decision-making on natural and physical resources draws attention to two considerations, namely, the need to (1) more adequately consider the use of earth's resources, with particular emphasis on conserving resources for future generations (i.e., better environmental stocktaking), and (2) more fully value the environmental costs of activities and policies in our decision-making process in order to protect our biophysical resources (i.e., better environmental valu-

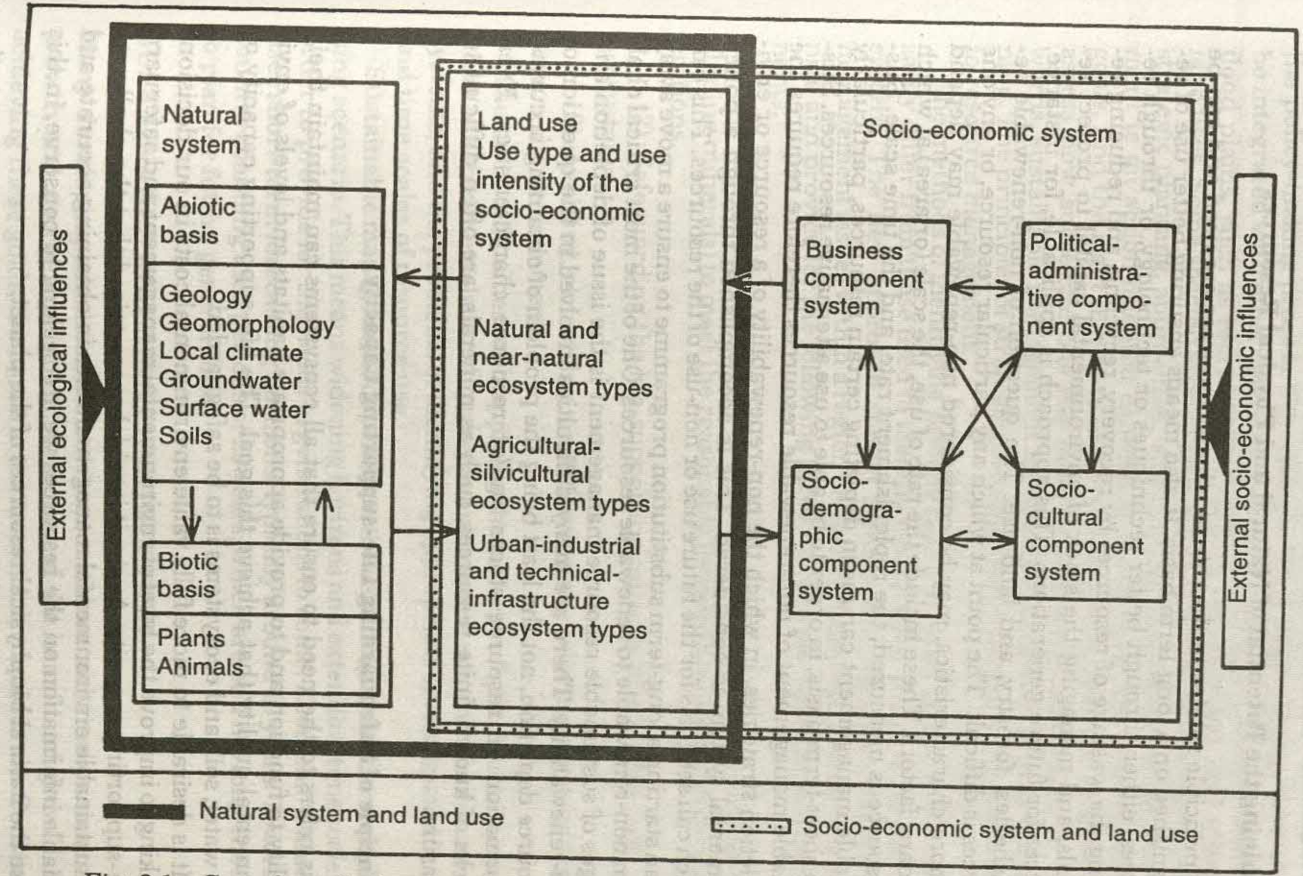
External ecological influences
Natural system
Abiotic basis
Geology
Geomorphology
Local climate
Groundwater
Surface water
Soils
Biotic basis
Plants
Animals
Land use
Use type and use intensity of the socio-economic system
Natural and near-natural ecosystem types
Agricultural-silvicultural ecosystem types
Urban-industrial and technical-infrastructure ecosystem types
Socio-economic system
Business component system
Political-administrative component system
Socio-demographic component system
Socio-cultural component system
External socio-economic influences
Natural system and land use
Socio-economic system and land use

Fig. 9.1 Complex relationships involved in an integrated model of a regional man-environment system (after Messerli, 1978).

ations). These considerations are connected, and the relationship should be recognized in policy- and decision-making.

Sustaining the Potential of Natural and Physical Resources

This principle relates to the rate at which resources are used and can be replenished on a long-term basis. It also means ensuring better use of resources, either through better techniques or technology, or through reducing the wastage of resources by recovery, recycling, and reducing residuals; and managing the stock of environmental capital to protect resources for future generations. This approach is applicable, for instance, to fisheries, forestry, and land use. The question of non-renewable resources is difficult. The point at which any particular resource, or any one or more characteristics, may be considered non-renewable may depend on many factors. These include the rate of use, the scale (or area) at which a resource is measured, the replenishment rate, and the time scale. Sustainable management can mean depleting certain resources, particularly on a short-term basis, in order to be able to use alternative resources. Sustainable management of non-renewable resources therefore requires the depletion strategies, in which the non-renewability of a resource or environmental system is considered. This is accomplished through a policy which can set goals for the future use or non-use of the resources. This can mean starting a long-term substitution programme to ensure a move away from non-renewable to renewable resources. One of the most critical challenges of sustainable resource management is the issue of depletion and non-renewability. There are many difficulties involved in the question of resource depletion, not the least being the problem of obtaining accurate information on resource stocks and/or resource characteristics. Even stocks of known finite resources, such as minerals, are often difficult to measure.

Principle of Safeguarding Life-supporting Capacity

This refers to the need to ensure that all ecosystems can maintain their ability to function and to provide appropriate habitats and levels of environmental quality that achieve this goal. The life-supporting capacity of air, water, soil, and ecosystems is to be safeguarded.

It is desirable to more fully value environmental costs in our decision-making to improve the level of environmental management and safeguard life-supporting capacity. Again, it is widely recognized that the challenge of sustainable environmental management lies in obtaining accurate and reliable information on the resources we are seeking to conserve, in this case the natural biophysical resources of the planet.

An important element of the concept of sustainable management is the interrelationship of resources, and their use, with the environment. Policy-making should not be a question of simply identifying issues in isolation from each other. What is needed is to identify the interconnections between resource issues. Policy integration therefore is a critical step in the policy-making process. For example, flood plain management should be integrated with other issues connected with the use of rivers and their flood plains, such as recreation, ecological conservation, and adjoining land uses. Some specific aspects relevant to achieving integration include strategic planning, approaches, and time horizons. Sustainable management is an action-oriented concept. It is based on the need to identify goals, find the right means to achieve those goals, implement them, and assess how successful one has been in achieving those goals. In other words, sustainable management is dependent on effective strategic planning. The principles of strategic planning therefore are of direct relevance to resource management.

The methods of identifying priority issues in resource use do not necessarily differ from those used to identify issues under the existing planning system. The new approach should identify the significant sustainable management issues within a region or district, based on the need to recognize and provide for the following three sustainable management components:

(1) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations.

(2) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems.

(3) Avoiding, remedying, or mitigating any adverse effects of activities on the environment.

The main difficulties with applying the concept of sustainable management are the interrelationships between resource use and environmental systems, and the problems of identifying appropriate levels (spatial limits) and time scales of resource use.

Sustainable management depends on the widening of our current planning scenario. This means widening horizons and extending time scales in order to provide for the needs of generations to come. Economic planning uses short-term forecasting horizons, typically around 10 years. Town and country planning uses periods of 20 years, which are still not long enough to plan for future generations.

SUSTAINABLE BUILDING CONSTRUCTION

Many developing countries are striving to achieve sustainable economic growth and a more equitable distribution of the benefits of growth. For achieving these goals, the construction sector has a major role. Construction is often second only to agriculture as a source of employment. Sustainable construction can contribute significantly to progress in developing countries.

Development goals can be achieved only if the physical infrastructure (water supply, electricity, roads, bridges, etc.) and buildings (industrial and commercial structures, schools, hospitals, and housing), i.e., outputs of the construction sector, are well developed. In many developing countries, the construction sector is a very important industrial sector. There is not a single human activity in which construction is not involved. Indeed, the building materials and construction industries are the basic means for the construction, expansion, improvement, and maintenance of all human settlements.

The construction sector is a major consumer of natural resources, such as timber, and a significant polluter of the environment. It is estimated that roughly half the world's coastal areas are threatened by activities in which construction plays a major role, particularly the use of inappropriate and unsustainable designs and building materials.

On the other hand, the construction industry generates many employment opportunities and is also necessary for meeting people's shelter needs. The solution lies in promoting the use of innovative and cleaner technologies which do not degrade the environment or threaten jobs.

Locally-available building materials, some traditional building techniques, designs, and construction skills can contribute to making architecture and building construction sustainable.

Very often it is possible to promote local capacity building in the building materials industry by adopting the following approaches:

(1) Improving the efficiency of investments and stimulating private sector investment in the sector through fiscal policies.

(2) Restructuring the industry with increased vertical and horizontal integration through such mechanisms as subcontracting and industrial estates.

(3) Reformulating and adopting building standards and by-laws to promote the use of low-cost building materials.

It is important to reduce the impacts of construction industry on the environment and to exploit its contribution to overall economic growth in such a manner that society at large benefits.

No doubt, the construction sector is one of the most important contributors to overall socio-economic development in every country, but it is also a major consumer of natural non-renewable resources and a significant polluter of the environment. About one-tenth of the global economy is devoted to construction and operation of residential and office buildings and one-sixth to one-half of the world's major resources are consumed by construction and related industries (Lenssen and Roodman, 1995).

The building industry alone probably consumes about 40% of the world's energy, some 25% of forest timber, and 16% of the world's freshwater. Close to 70% of sulphur oxides produced by fossil fuel combustion are produced through generation of electricity used to power our homes and offices (Dimson, 1996). Some 50% of carbon dioxide emissions (mainly in industrialized countries) come from operations in buildings-in-use (heating and cooling). Indoor air quality is inadequate in 30% of buildings around the world (Der-Petrossian, 1999).

It is expected that the current trends in construction practices will change in many countries so as to provide better living conditions for our future generations. While in industrialized countries some actions have been taken to arrest the implications of resource depletion and environmental degradation caused by construction activities, developing countries have not made any significant progress in this area; many of them lack resources and capacities to improve their technologies, because many have a fragile environment and are at risk of threats involving natural disasters such as aridity, desertification, earthquakes, storms, and floods, not to mention the rapid population growth with all the associated social, economic, and environmental problems (Der-Petrossian, 1999).

Roughly half of the world's coasts are threatened by development-related activities in which construction plays a major role. The marine environment is degraded by removal of coral and shells for the production of lime and for use as aggregates.

Timber is extensively used both as structural support for buildings and bridges and also for decoration. Indiscriminate use of timber has destroyed or depleted tropical forests. Inefficient commercial logging operations and the use of wood as fuel have resulted in deforestation in many regions. The rate of deforestation in primary forests in the Asia and Pacific region in the early 1990s was about 1.8 million hectares per year, an increase of approximately 80% since the early 1970s. Managing the forests sustainably needs to attract high priority.

One way of tackling the problems associated with deforestation is encouraging the use of commercially less accepted and industrial tree plantation species. If properly managed and exploited, these species can serve as abundant and renewable resources of building materials within the reach of the majority of the population.

The construction industry is a major consumer of natural non-renewable resources such as metals, fossil fuel, and non-renewable energy sources.

The construction industry contributes considerably to air pollution through emissions of dust, fibres, particles, and various toxic gases. At a global level, the main pollutants are emissions of greenhouse gases which are produced mainly during the production processes of basic building materials such as steel, cement, lime, bricks, and aluminium.

Besides the emissions from energy-intensive processes, an additional contribution to global carbon dioxide levels comes from energy consumption in buildings-in-use. In some industrialized countries, up to 50% of global carbon dioxide emissions arise as a result of building operations (particularly heating). Therefore, using energy-efficient building designs, techniques, and operations is becoming an attractive strategy for environmental protection.

SUSTAINABLE ARCHITECTURE

Sustainable architecture may be defined as building that will stay intact for a long period. Traditional planning and building methods were often good examples of sustainable architecture in olden times, and represented good uses of local resources matched with local skills. The growing interest in indigenous building methods over the past few decades reflects the wide appreciation that there are many lessons to be learnt that can contribute to meeting contemporary and future building and planning needs. But demographic growth, shifts from rural to urban areas, natural and man-made resources depletion, and significant changes in expectation and lifestyle, together erode the viability of traditional approaches to shelter provision.

Whilst there are some aspects of traditional approaches that still work well, some aspects may have become inefficient or unworkable, or unsustainable.

Between the declining viability of some traditional solutions and the inaccessibility of many modern alternatives, sustainable architecture is an approach that may bridge this gap. It has a focus on the process as well as the end-product. It implies that while the product may wear out over time, the process remains.

Sustainable architecture brings together the following five key characteristics:

(1) Environmental sustainability.
(2) Technical sustainability.
(3) Financial sustainability.
(4) Organizational sustainability.
(5) Social sustainability.

In practice, there is always a compromise between one or the other of these characteristics, in as much as a single aspect may be achieved only to the slight detriment of one of the others. Financial sustainability, for example, may apply only to certain socio-economic groups, namely, those who have access to housing finance. Environmental sustainability may be slightly compromised if it is compensated by financial sustainability and accessibility (Norton, 1999).

A good sustainable architecture may be assessed on the following bases (Norton, 1999):

(1) It makes substantial use of locally-available materials and local means of transport.

(2) It uses resources that are available in sufficient quantity to satisfy a general demand and not damage the environment.

(3) It does not depend on equipment that is not easily available.

(4) It uses skills that can be realistically developed in the community.

(5) It can be afforded within the local socio-economic context.

(6) It produces a durable result.
(7) It responds to and resists the effects of the local climate.
(8) It provides flexibility to adapt to local habits and needs.
(9) It can be replicated by the local community.

SUSTAINABLE LIVING THROUGH HEALTH PROMOTION

The World Conservation Strategy, prepared in 1980 by IUCN (International Union for the Conservation of Nature and Natural Resources), defined conservation as "the management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations". This concept has been widely accepted by governments, development agencies, and conservation organizations. The issue is no longer whether conservation is a necessary part of social and economic development, but rather *how* it can be achieved. If protecting natural areas serves basic human needs, the chances of survival for natural areas usually increase (Cesario, 1996). Linking protected areas to human needs may in several cases support ecologically-sound development.

It is being realized that human beings are at the centre stage of concerns for sustainable development, and also are entitled to a healthy and productive life in harmony with nature. Therefore, to achieve sustainable development, environmental protection should be an integral part of the development process and should not be considered in isolation from it. However, to find ways of demonstrating that the conservation of nature and the sustainable use of natural resources have a fundamental relevance to the daily lives of people is a complex and daunting task.

Cesario (1996) reviewed the interrelationship between human health and conservation, and how this enables people to sustain their living and increase their commitment to neighbouring national parks and protected areas.

Health is nothing but a state of physical, mental, and social well-being; it is much more than the absence of disease or infirmity. Conservation, leisure, culture, housing, etc., should be viewed as components of mental and social well-being, and therefore regarded as basic to human health.

The primary health care comprises actions related to health promotion, disease prevention, disease treatment/cure, and individual rehabilitation. Health promotion and rehabilitation regard the person as a whole. On the other hand, prevention and treatment/cure consider the sick person (the patient).

Health promotion deserves high priority as part of conservation community rethinking of the role of national parks and other protected areas in society and the economy. Conservation projects for protected areas ought to be well integrated with sustainable rural development projects, i.e., health-promoting projects, for those directly affected by the existence of the protected area (Cesario, 1996). Cesario has demonstrated that the linkage between health and conservation enables local communities to sustain their living and increase their commitment to the surrounding protected areas.

CONCEPT OF BOTTOM LINES

Sustainability requires finding appropriate levels of resource use, a process expressed as identifying bottom lines. The bottom line is the point of modification beyond which there is a high risk that the life-supporting capacity or the sustainability of a resource is endangered. Exceeding this threshold would result in the irreversible exhaustion of a resource or the extinction of an ecosystem. If the resource use pattern indicates that a particular resource or ecosystem will be taken below the bottom line, then action is needed to remedy this. The concept may be used as a strategy which seeks to protect or conserve a particular resource or ecosystem, by ensuring that little or no use or development occurs in the future. This is called the top line of sustainable management, in which preservation or conservation is the primary goal.

The concept of bottom lines can also be used to assess the appropriate standards of environmental conditions according to human values. The bottom line approach does not imply advocating a mathematical quantitative approach to resource management, in which quantities are determined, levels of sustainability numerically based, and lines drawn. Rather, it illustrates in graphic form the philosophy of good environmental management.

SUSTAINABLE MANAGEMENT AND ENVIRONMENTAL BOTTOM LINE

Many people now feel that there is a need for environmental bottom lines (EBLs) in relation to sustainable management of natural and physical resources. Environmental bottom lines are not synonymous with sustainable management itself. Instead, they should be seen as part of a planning framework involving the establishment of clear environmental outcomes and a range of possible approaches and instruments for achieving those outcomes. Superficially, the EBL appears to be a relatively simple concept. Brash (1992) defined an EBL as "the boundary or limit beyond which there is a high risk that the quality of the environment will be unacceptably degraded". In practice, establishing EBLs is rarely simple because of debate over which qualities of the environment are important, the degree of risk involved, and what level of degradation is acceptable. This is due primarily to three factors, viz., (1) complexity and lack of knowledge of biophysical systems; (2) subjectivity of human perception of the environment; and (3) uncertainty over how social and economic systems affect, or are affected by, biophysical systems.

The issue is further complicated by the fact that, although EBLs are often equated with environmental standards, the term can also be used to include a wider group of policy instruments. A standard normally relates to some specific characteristic and is usually expressed in some measurable form. Environmental bottom lines are often used to cover more general objectives or policies which are aimed at a particular outcome (e.g., to maintain and enhance the current area of native forest), or related to specific development controls (e.g., prohibit nuclear power stations).

Ecosystems are normally very complex and our understanding of them is often incomplete. These systems can be viewed scientifically as a combination of interacting and interdependent physical, chemical, and biological processes. The following are some key problems encountered in establishing EBLs for such systems.

In order to understand these systems, we usually have to study the component parts to determine how they vary and how they may react to a human-induced change. Figure 9.2 illustrates this variation using a relatively simple example of how changes in river flow can alter the concentration of substances, such as sediment, in the water. Mitigating such effects may be less complex in the case of dilution, where discharges could be required to stop if flows were insufficient, but more complex in other situations where there is not a simple relationship with the flow, e.g., sediment during storm events.

Regardless of the EBL type, it is usually difficult to establish that a given concentration is an appropriate EBL. Toxicity will most likely depend on other environmental conditions (e.g., temperature) and there are often subtle sublethal effects which are hard to measure (e.g., effects on reproduction). In these situations, there is always an element of uncertainty and an assessment of risk is required. Where the impact is potentially irreversible or widespread, the normal approach is to be conservative and to build in safety factors (the precautionary approach) (Brash, 1992).

Certain substances can also accumulate or magnify due to biological processes, to the point where they can affect the environment (e.g., organochlorines in the fatty tissues of birds). Furthermore, some substances can interact in the environment and have significantly greater effect because of this, while others quickly degrade into harmless substances (Fig. 9.3). This means that EBLs must also consider any effects of processes occurring at some other place or time.

Likewise, biophysical systems are usually classified according to distinctive characteristics or identification of indicator species (e.g., maps of soil characteristics, and vegetation composition over a period of time). If carefully selected, biological indicators can make very useful EBLs. For example, changes in moss-lichen flora are usually good indicators of SO_2 air pollution. Biophysical systems can also act as self-purification systems. For example, the effect of an organic waste discharge in a river is to reduce dissolved oxygen and alter aquatic species downstream until the waste is biodegraded (Fig. 9.3). In this case, an EBL should relate, firstly, to the

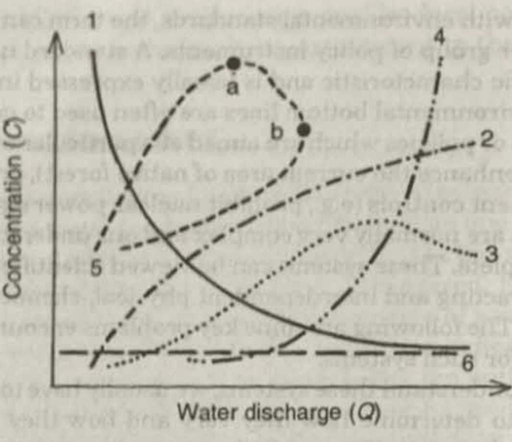

Fig. 9.2 Various patterns of *C* versus *Q* in rivers. 1, a general decrease in concentration with discharge which implies a dilution, generally from point sources; such a pattern is widely observed for most major ions, particularly for the most mineralized waters; 2, a limited increase, generally linked to the flushing of soil constituents (organic matter, *n* species) during run-off; 3, a maximum, sometimes observed when very high run-off dilutes soil waters; 4, an exponential increase, characteristic behaviour of suspended particulate matter and of attached components (metals, pesticides, etc.); 5, a clockwise loop, a pattern often seen for suspended matter during floods, the maximum turbidity (a) occurring before the maximum water discharge (b); 6, a constant concentration when the groundwater contribution to the river flow is dominant as in karstic regions. (After Maybeck *et al.*, 1989.)

maintenance of the self-purification system and, secondly, to whether the reduction in water quality immediately downstream is acceptable (Brash, 1992).

Since the effects also depend on the nature of the receiving environment, the assimilative ability can vary radically between one environment and another; this means that it is often difficult to transfer EBLs from one location to another (Brash, 1992).

Different environments often react quite differently to stress. Some can withstand the effects of an activity for long periods with minimal local effects, but they can then suddenly reach a threshold and radically change to another state. Assuming an ability to predict life-supporting capacity thresholds, EBLs should be established to avoid such radical changes.

Figure 9.4 brings out how different types of land use may affect sediment yield, and illustrates the more gradual changes associated with agriculture and more rapid changes associated with the construction of houses. Similarly, eutrophication of lakes is a natural phenomenon which

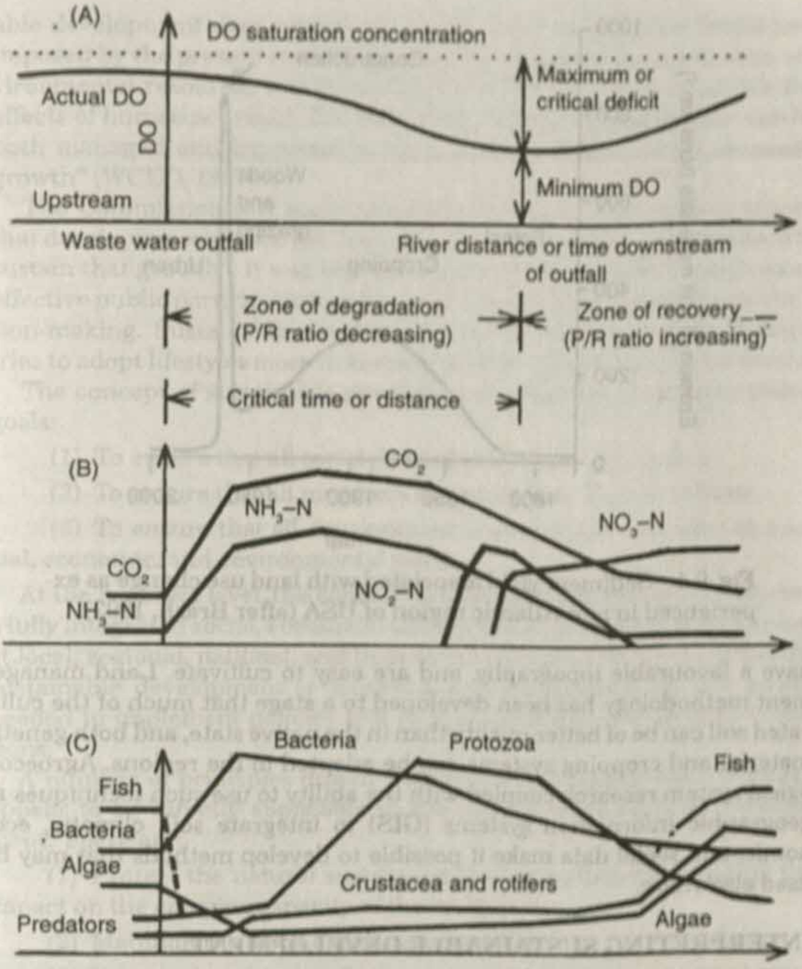

Fig. 9.3 Influences on dissolved oxygen (DO) levels downstream from waste water outfall. A, self-purification; B, presence of nitrogen compounds and carbon dioxide; C, dominant organisms. (After Maybeck *et al.*, 1989.)

can be accelerated by nutrient sources such as agriculture and sewage discharge.

Some research has been done on land management for sustainable agriculture with examples taken from tropical savannahs. These very fragile ecosystems are under great population pressure. They tend in their natural state to contain highly infertile soils that also contain high quantities of active aluminium, are subject to compaction when cultivated, and develop in areas where there is a period of the year with inadequate rainfall. On a positive side, the soils are usually deep, have good drainage properties,

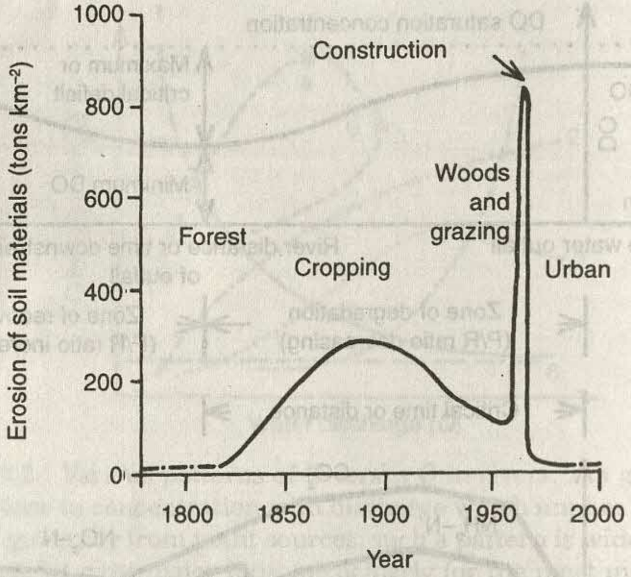

Fig. 9.4 Sediment yield associated with land use change as experienced in mid-Atlantic region of USA (after Brash, 1992).

have a favourable topography, and are easy to cultivate. Land management methodology has been developed to a stage that much of the cultivated soil can be of better quality than in the native state, and both genetic material and cropping systems can be adapted to the regions. Agroecological system research coupled with the ability to use such techniques as geographic information systems (GIS) to integrate soil, climatic, economic, and social data make it possible to develop methods that may be used elsewhere.

INTERPRETING SUSTAINABLE DEVELOPMENT

The concept of sustainable development rose to prominence in the 1980s in response to a growing awareness of the need for action on such global issues as environmental degradation, resource depletion, and socio-economic inequities (Gardner, 1991).

Sustainable development is a challenging concept because it is both simple and complex. The most commonly used definition of sustainable development is that given in the Brundtland Commission Report (WCED, 1987). It describes sustainable development as being development that meets the needs of the present without compromising the ability of future generations to meet their own needs. However, applying this general prescription to operational situations requires considerable thought. This is the challenge presented by the Report. The Brundtland Commission saw sustainable development as leading to the reduction of poverty through environmentally-sustainable economic growth: "The concept of sustainable development does imply limits—not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities. But technology and social organization can be both managed and improved to make way for a new era of economic growth" (WCED, 1987).

The Commission saw sustainable development as a means to ensure that developing countries get "their fair share of the resources required to sustain that growth". It was also the way to achieve equity through more effective public participation and greater democracy in international decision-making. Sustainable development would require developed countries to adopt lifestyles more in keeping with the planet's ecological means.

The concept of sustainable development comprises three interrelated goals:

(1) To ensure that all society's *needs* (not wants) are met.

(2) To ensure that all members of society have their needs met.

(3) To ensure that all development is sustainable over time in a social, economic, and environmental sense.

At the broadest level, the concept of sustainable development requires a fully integrated social, economic, and environmental policy to be applied at local, regional, national, and international levels. The key to achieving sustainable development is acquiring and maintaining the will power needed to implement policies and to make difficult—and painful—decisions.

A number of principles drawn from the World Conservation Strategy appear to be directly applicable to the concept of sustainable development. These are:

(1) Protect the natural sustainability of ecosystems by limiting the impact on the carrying capacity of the biosphere.

(2) Maintain the stock of biological wealth.

(3) Ensure that the use of non-renewable resources occurs at rates that do not exceed the substitution of renewable resources.

(4) Achieve a more equitable distribution of the benefits and costs of resource use and environmental management.

(5) Promote technologies that increase the benefits from a given stock of resources.

(6) Use economic policy to help maintain natural wealth.

(7) Adopt an anticipatory cross-sectional approach to decision-making.

(8) Promote and support cultural values compatible with sustainability.

STRESS-RESPONSE ECOLOGY

Multistressed ecosystems tend to show degradation syndromes with synergism among the consequences of different stresses. A variety of stresses acting separately and jointly can trigger somewhat similar symptoms, so that diagnosis of the cause of degradation becomes difficult. Such synergism has great relevance to environmental assessment of a new stress or of intensification of existing stresses (see Clark and Munn, 1986).

Some workers (e.g., Muir *et al.*, 1987; Regier, 1991) have attempted to review and study interdisciplinary stress-response ecology by undertaking comparative study of the Baltic and Great Lakes Basins with the focus being on sustainable redevelopment.

EQUITY AND SUSTAINABILITY

It seems certain that a fairer world would be a more sustainable world. The current income gap between developed and less developed countries makes the latter suspicious of rich, overconsuming countries preaching resource constraints to the poor. Yet humankind's only chance of creating a sustainable civilization depends strongly on global cooperation (Daily *et al.*, 1995). The scale of the human enterprise needs to be brought down so that the size of the human population is brought within the earth's carrying capacity. This means that countries must agree to regulate rates of utilization of both natural resources and of the natural sinks that absorb effluents. Each country must also accept limits on the resource flows that it can command—only so many litres of water will be extracted from rivers with international basins, only so many cubic metres of lumber, etc. There should be some limits on reproduction and per capita consumption, everywhere. Everyone needs to realize that the present scale of the human enterprise constitutes a general threat to the sustainability of civilization.

A substantial narrowing of the rich-poor gap should form a key factor in any negotiations to reduce the scale of the human enterprise. One good plan for how the gap might be narrowed was proposed by Holdren (1991, 1992). His proposal for the twenty-first century is based mainly on maximizing the efficiency of energy use. In his scenario, poor nations would develop fast enough to increase their per capita energy use by 2% annually between 1990 and 2025, doubling it from 1.0 kW to 2.0 kW. Simultaneously, rich nations would strive to reduce their per capita use by 2% annually through increased efficiency, reducing their use per person from 7.5 kW to 3.8 kW.

Population increase in rich nations, from 1990 to 2025, is expected to be about 15%, and in developing nations will increase by about 65%. Then, in the remainder of the twenty-first century, rich and poor nations would converge on an average per person energy use of 3 kW, thereby eliminating inequity. Meanwhile, the world population peak size of 10 billion people would be reached around 2100 after which it would decline. When the peak is reached, total energy use would be 10 billion × 3 kW, or 30 TW (see Table 9.1).

Table 9.1 The Holdren scenario (after Holdren, 1992; Daily *et al.*, 1995)

Year	Nations	Population × (billion)	Energy/person = (kilowatt = kW)	Total energy use (terawatt = TW)
1990	Rich	1.2	7.5	9.0
	Poor	4.1	1.0	4.1
		5.3		13.1
2025	Rich	1.4	3.8	5.3
	Poor	6.8	2.0	13.6
		8.2		18.9
2100		10	3	30

Urban-rural inequity influences carrying capacity in complex ways. Reducing urban-rural inequity may increase consumption which, in turn, may have adverse effects on carrying capacity.

The rich-poor gap also is a source of high fertility among the poor. Development may be the best contraceptive. The main problem with development (in the classic mode) as a contraceptive is implicit in the Holdren scenario. Earth cannot sustainably support even today's 5.8 billion people if everyone lived the consumptive lifestyle of rich nations. Population limitation by development of that kind would eventually amount to population limitation by raising death rates (Daily *et al.*, 1995).

Daily *et al.* (1995) concluded that:

(1) In general, increasing equity at any level will tend both to increase carrying capacity and decrease fertility.

(2) A critical exception to the conclusion in (1) would be an attempt to increase equity by raising consumption everywhere to the per capita level now seen in industrialized nations.

SOCIO-ENVIRONMENTAL INTERACTIONS

As compared to previous developmental approaches, sustainable development appears to be more effective in overcoming problems of poverty, social inequity, and environmental decline by focusing on the importance of sustainable resource management on both the micro- and the macro-levels. It has some promise of being able to deal with some of the deficiencies of the standard development models. A critical analysis of social, political, and economic factors is essential for an understanding of the dynamics of successful sustainable development.

Some of the issues centred on social and environmental interactions are grass roots environmental initiatives and movement, social origins and effects of deforestation, indigenously-developed resource management systems, social aspects of the urban environment, environmental impacts of population dynamics, and social aspects of water quality and availability.

Considerable attention has recently been paid to environmental issues in the Third World. Yet the difficulties in attaining the goal of sustainable development have not diminished. New ways have to be found to address the problems of environment and development: the implementation of conservation policies and the passing of legislation governing human interaction with ecosystems have not proved to be sufficient. Technologies are seldom adopted on a scale large or broad enough to make a major impact on environmental degradation, while policies frequently fail to achieve their objectives, and environmental protection laws, especially in the Third World, are often either unenforced or unenforceable.

One basic reason for the lack of success in achieving adequate sustainable development is the failure to include an analysis of the social factors influencing human interactions with the environment when development policies and programmes are formulated. Environmental degradation is not a purely physical process; it is also a social one and, especially in the Third World context, is largely determined by the combined decisions and actions taken by vast numbers of individuals on the local level (Anonymous, 1992). To be effective, sustainable development programmes have to be based on an understanding of what makes people adopt or resist such programmes, what makes technologies appropriate or inappropriate in particular contexts, and the circumstances under which local people are themselves able to determine sustainable techniques of resource use. Social processes are often treated as a 'black box' which helps to determine the end results of sustainable development efforts, but whose workings cannot be understood or influenced.

The need for local-level action to prevent or reverse environmental degradation is very strong. Local actions both affect, and are affected by, local, national, and international dynamics; lines of causality are generally not simple and unidirectional but are complex and multidirectional. This warrants a holistic approach in considering the problems of environment and development. The prevalent models of environmental dynamics offer simple accounts of how environmental degradation occurs due to, for instance, poverty or overpopulation; such models have been useful in providing an initial level of understanding and awareness of environmental problems. But real progress in promoting sustainable development will depend on a much better understanding of the range of factors which determine the opportunities, incentives, and constraints affecting the local people who must bear primary responsibility for implementing sustainable development.

SOCIAL ORIGINS AND IMPACTS OF ENVIRONMENTAL DEGRADATION

Environmental degradation can rarely, if ever, be attributed to one or two simple causes such as population growth and the practices of poor farmers; it is rather the outcome of a multiplicity of interconnected factors linked primarily to processes of modernization, market integration, and marginalization. The dissolution of traditional self-provisioning systems caused by cash crop or export crop production has occurred in a context where alternative employment opportunities are difficult to come by, with the result that many choose to clear forest areas and overexploit other natural resources (Anonymous, 1992).

For an understanding of why environmental degradation occurs, it is important to focus on the factors directly leading to increased pressure on the natural resource base, such as demand for fuelwood (Somanathan, 1991), and land clearance for pastures and crops. Other important factors can lead to the breakdown of traditional resource management systems. In many regions, these systems have provided some measure of food security and environmental protection. They were often characterized by mechanisms for reducing risk, providing social security, and protecting the environment. These mechanisms might include, for instance, asset-sharing, income redistribution, maintaining surplus capacity and biodiversity, and long crop-fallow rotations. Factors accounting for the breakdown of resource management systems include population growth, influx of outsiders, replacement of customary tenure regulations by state laws, and restricted employment opportunities which increase pressure on the natural resource base (Anonymous, 1992).

Government policies are often contradictory, with some actively-promoting and others seeking to arrest environmental degradation. Policies promoting changes in land tenure or the failure to protect customary tenure rights have often accelerated processes of environmental degradation. Very often it is the poor and vulnerable who suffer most from environmental degradation associated with increasing shortages of essential natural resources and contamination of those resources.

The impacts of environmental degradation take many forms. Most importantly, people's livelihoods and productive capacities suffer as a direct result of the depletion or misuse of the natural resources on which they depend. The health consequences are often also severe, and environment-related illnesses take a further toll (Anonymous, 1992). Nutritional status is also affected. Both economic and psychological stresses arise from the displacement of individuals or communities from degraded areas, and social conflicts increase because of increasing pressures on the natural resource base, competing claims on scarce resources, and the upsurge in illicit activities centred on the exploitation of natural resources, especially forests.

ENVIRONMENT AND DEVELOPMENT: TRADE-OFFS AND POSITIVE LINKAGES

The existence of positive linkages between environmental conservation and equitable development has nurtured the concept of sustainable development to gain much support from environmentalists, economists, planners, and activists. But still there have been difficulties involved in formulating specific sustainable development policies. In many developing countries, more individuals depend directly on natural resources for their livelihood than do people of the developed countries of the North. This means that the possibility of positive linkages between environment and development is clear in the developing country context. Soil erosion, deforestation, and other natural resource depletions adversely affect people's production and their level of living. Measures to prevent environmental degradation or to restore natural resources therefore have a potential for benefiting those in greatest need of development assistance. But the presence of widespread conflicts over natural resources and environmental conservation policies in the Third World indicate that positive linkages are not always easy to attain in practice.

Two types of conflict are important in the context of sustainable development: one, in which people organize to protect ecosystems and cultures endangered by policies which are of benefit to another group; and two, in which people protest conservation-related policies or programmes which threaten to impinge on their livelihood. The first case is exemplified by the Chipko activists in India, and the forest dwellers of Malaysia, threatened by unsustainable resource extraction. People oppose large dams, agricultural schemes or other infrastructure which will destroy their resources and jeopardize their way of life. The second type of conflict involves displacement of communities in order to establish parks and nature reserves, in the name of preserving the environment.

Programmes designed as ecological conservation measures can create substantial hardships for those directly affected by them. When environmental reserves are necessary as the only way to protect threatened ecosystems, or when conservation programmes become imperative to avert environmental degradation, the question of who will bear the costs of such measures should be adequately addressed if conflicts which prevent the goals of the programme from being met are to be avoided. However, an emphasis on livelihood issues should not obscure valid environmental concerns. There are sometimes adverse environmental impacts of introducing even those production-oriented agrarian reforms which are intended to improve the living conditions of the poor. Preserving the environment in its present state is not always advisable. Care must be taken to recognize ecological constraints to any such transformation—the typical inability of rain forest soils to sustain agriculture, for instance, or the very real costs of destroying ecosystems to the point of reducing biodiversity. The guide to balancing these conflicting considerations regarding the goals of sustainable development should be local-level concerns, needs, and aspirations.

Local-level action which affects the environment can be either individual or collective, and can be positive or negative. It is usually believed that the poor have no option but to destroy their environment in order to obtain their short-term survival needs. The fact is that at times the poor do degrade their environment, but at other times they effectively manage it, or they act to protect it from outsiders who try to plunder its resources. Many traditional systems of resource management show a high level of awareness of ecosystem dynamics, indicating that an approach to sustainable development primarily based on environmental education would have its emphasis misplaced.

Environmental degradation is quite often a product of the economic history of social and productive systems. Similarly, people's reactions to such degradation are constrained by several social and economic factors. Several factors have contributed to the decline in the effectiveness of traditional resource management systems. Shorter and shorter fallow periods, increasing pressure on grazing lands, and increased extraction of forest products may be attributed, at least in part, to growing populations.

Resource deterioration is not an immutable process. People respond to environmental stress by changing their production techniques, their consumption patterns, or migrating. The particular options which are open to them in the context of reversal of environmental degradation is a function of the existing social, economic, and technological conditions.

Sustainable development requires local action in most contexts. Such action can be proactive, developing and implementing sustainable resource management systems; it can be cooperative, contributing local efforts to environmental protection or rehabilitation programmes which originate outside of the community; or it can be oppositional, defending local resources from overexploitation (Anonymous, 1992).

However, local action is sometimes constrained by economic, political, and social circumstances at the local, national, and international levels.

ENDOGENOUS DEVELOPMENT

Endogenous development refers to development based chiefly on locally-available resources such as land, water, vegetation, local knowledge, culture, and the way people have organized themselves. It strives to optimize the dynamics of these local resources, thereby enhancing cultural diversity, human welfare, and ecological stability. It is a response to the current process of global modernization which, in many respects, tends to have opposite effect.

The importance of indigenous knowledge is now increasingly recognized. Many indigenous farming techniques have been documented. Much literature exists on soil and water conservation, ethnoveterinary practices, use of natural pesticides, intercropping, agroforestry, food preservation, and human health.

Conservation is not simply to ensure balanced biological diversity. It also helps to preserve the relationship between the human, natural, and spiritual worlds. Traditional institutions should be the custodians of all cultural activities and should ensure that rituals and ceremonies are performed in accordance with the strict procedures, rules, and regulations laid down by the spiritual leaders.

Experience in Africa has shown that communities take good care of trees planted in the traditional spiritual context and that their survival rate is quite high. Activities at village level include tree nurseries, tree planting, gardening, and water management. Village centres are built where traditional tools, indigenous seeds, and spiritual objects can be collected, preserved, and demonstrated (Gonese, 1999).

Endogenous development implies strengthening of traditional institutions. It is a political rather than a technical activity that leads to better management of natural resources by the people themselves. Communities agree on what is needed to promote their natural environment and start suitable projects. Understanding the range of perceptions related to the need for natural resource management may well be one of the keys to successful field activities in rural development.

During the last few decades, considerable modernization has swept the European countryside and affected farming. Global parameters such as the common market and the newest technologies have penetrated everywhere. The European Union has strongly supported the employment of generic new technologies in the interest of enhancing common agricultural policy productivity. The adverse aspects of the modernization process have appeared. In highly intensive agricultural areas (e.g., the Netherlands), serious ecological problems have arisen. Soil, water, and air are heavily affected; biodiversity and natural landscape are under attack and animal welfare and the quality of food are causing increasing concern. All this has stimulated a search for alternatives to modernization.

Although the effect of modernization in Europe has been one of globalization, its real scope and impact have probably depended on responses developed at the grass roots. The modernization model is characterized by intensification, scale enlargement, specialization, and integration into agribusiness chains. The current heterogeneity of European agriculture shows that agricultural development is a many-sided and highly variable interaction between the local and the global, and that diversity continues to be one of the main features of European agriculture.

The diversity of European agriculture arises not only from differences in climate, soil, physical distance from centres of consumption as well as historically-created land use patterns but also from the social and cultural aspects and the way agricultural practice is organized by various individuals and organizations. These actors decide on the strategies used, the ways in which practices are linked to markets and technological developments. It is these actors who determine the interaction between their farming activities and regional, national, and international policies and interventions. These are the decisive elements in the complex process that makes agricultural practice what it is: a highly diversified whole (van der Ploeg, 1999).

Endogenous development can be clearly characterized by contrasting it with the patterns frequently observed in exogenous development: (1) endogenous development is locally determined whereas exogenous development is transplanted into particular locations and externally determined; (2) endogenous development leads to higher levels of retained benefits within local economies whereas exogenous development exports the proceeds of development out of the region; (3) endogenous development respects local values whilst exogenous development tends to trample over them; and (4) endogenous development is founded mainly on locally-available resources, including local ecology, labour force, knowledge, and patterns for linking production to consumption. Endogenous development can revitalize and dynamize local resources which might otherwise be ignored as being of little value (van der Ploeg, 1999).

INDIGENOUS AGRICULTURE IN CHITWAN VALLEY (NEPAL)

In some villages of India and Nepal, the farming system is based on locally-available natural resources and a great respect for Mother Earth. Traditional soil conservation methods include keeping animals for manure, part of which is brought to the uplands, especially prior to sowing maize and mustard. Composting, growing legume crops in rotation with agricultural crops, and mixing cereals with legumes are even now some other common practices amongst the Tharu Nepalese farmers.

Farm animals are kept for manure, milk, and traction. As the rice grows, the animals graze and manure the fields, public lands, forests, and river banks. These animals are important for the family economy as they can be exchanged in times of need. Before 1960, the Tharu had a small local cattle breed of cow and they did not keep buffaloes. Milking was not common; most milk was given to the calves. But after the establishment of the Royal Chitwan National Park, it became impossible for the farmers to let their animals graze in the forests and river banks. The number of cows decreased and some were replaced by buffaloes. Buffaloes produce more manure than the local cows. But products from cows are highly valued by the Tharu for purifying places of worship and for cleaning their houses. Buffalo manure is suitable only as fertilizer.

Legumes and other green manuring plants such as lentil, lathyrus, and gram are commonly used in the irrigated lowlands after paddy rice has been harvested. In the uplands, cowpeas and various types of beans are common; they are planted throughout the year as an intercrop with cereals and as a main crop before cereal or oil-seed crops are planted. Other plants with green manuring properties are *Adhatoda*, *Albizzia*, and sesame. Sesame is considered a sacred grain crop and is used in rituals. It is also an indicator plant that reflects the fertility of the soil. If sesame does not grow well, no other crop grown in that field will give a good harvest. Tharu people also use wood ash from certain (unidentified) trees, which they consider rich in nutrients, to strengthen crops against diseases and pests.

Chemical fertilizers are now replacing traditional methods of managing soil fertility. Older farmers believe that chemicals damage the soil, because more and more chemical fertilizer would be needed each year to maintain yields. If rainfall is good during the monsoon, it is possible to get good biomass and this can be converted into compost when it is mixed with manure (Ghimire, 1999). Use of chemicals increased greatly during the Green Revolution. Plots near the homestead, however, are still fertilized only with organic manure. These plots are used to grow vegetables and cereals for home consumption. Many older, orthodox farmers practise this even today.

Figure 9.5 illustrates some of the elements involved in an integrated, ecofriendly farming system within the Tharu framework.

Globalization of economies, population growth, and urbanization have caused serious threats to the life-supporting systems of farmers and indigenous communities in many areas of India. As rural values and lifestyles change, the need to conserve the natural resource base assumes greater importance (Ramprasad *et al.*, 1999). Green Foundation is a grass roots organization working with small farmers towards conserving, promoting, and reviving genetic and cultural diversity in South India. There is considerable significance of traditional knowledge systems and spiritual beliefs in the life of several people who depend on the vagaries of nature in carrying out agricultural activities.

In Sri Lanka also, agriculture has traditionally been an integrated system with crops, trees, livestock, and fish. Animal and crop production is based on three aspects: ecologically-sound practices, astrology, and relation with spirits and supernatural beings (Upawansa, 1999).

An ecoagricultural approach is being actively introduced into new areas. A network of farmers, local leaders, and government agents interested in the ecoapproach identify new areas. Criteria include the interest of the farmers in experimenting with ecopractices, and the level of damage to the environment. Knowledgeable persons having special knowledge of traditional farming and astrology are then identified.

Each trained farmer establishes a plot in his field for ecopractices, inviting some other farmers to observe, analyze, and discuss the results. Some field advisors of NGOs (non-governmental organizations) give intensive guidance during the phase of experimentation, and they live and work in the village with the farmers. The field workers well appreciate the traditional farming practices, survival strategies, knowledge, and customs, and they must show respect for the culture, norms, leadership structure, and spirituality in the community. Field workers also are open to learning from farmers' experiences and their local knowledge and spirituality. Astrology

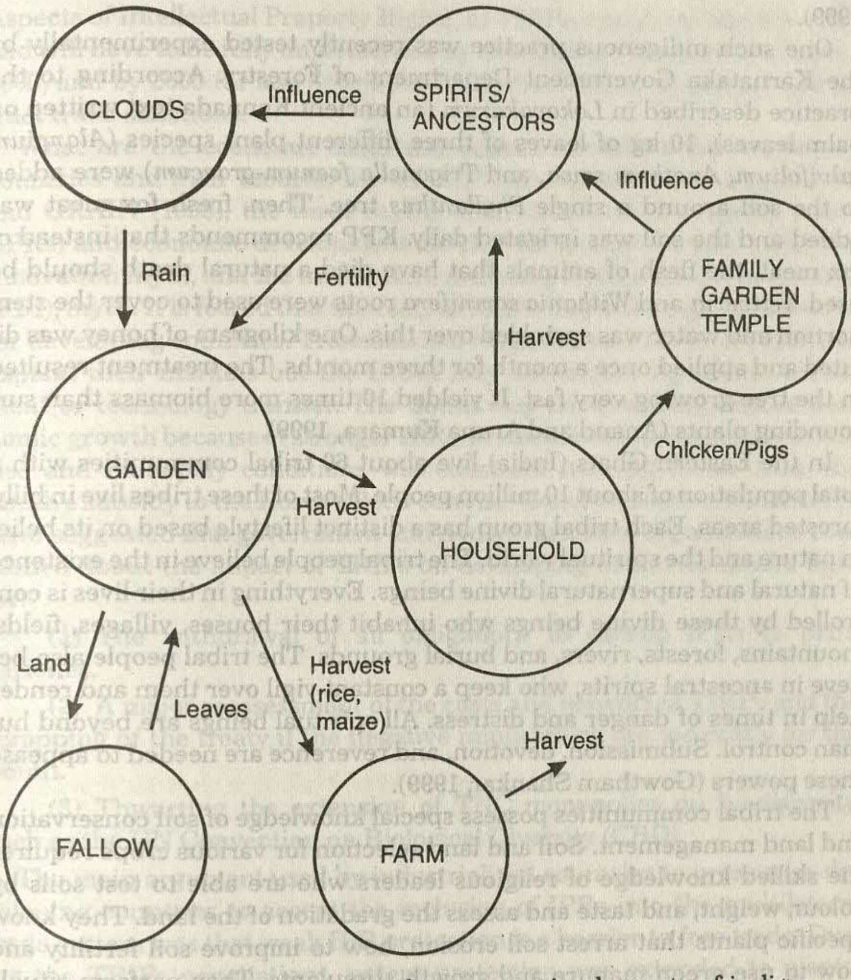

Fig. 9.5 Some relationships between main elements of indigenous natural farming system of Tharu people (after Kieft, 1999).

is used to decide auspicious planting dates (Upawansa, 1999).

The Krishi Prayoga Pariwar (KPP) in Karnataka, India, is engaged in three activities: promoting ecofriendly agriculture, revitalizing local health traditions, and educating young people for their future roles as traditional leaders in their communities (Anand and Aruna Kumara, 1999). KPP collects information on present farming practices as well as ancient agricultural texts on palm leaves. It is designing on-farm research for testing existing practices, and supports revalidation of the ancient practices described in old texts. Tests are carried out to measure the efficacy of a technology. Through experimentation, modifications to indigenous practices are developed which enhance their productivity and their relation to ecological circumstances or cultural context (Anand and Aruna Kumara, 1999).

One such indigenous practice was recently tested experimentally by the Karnataka Government Department of Forestry. According to the practice described in *Lokopakarum* (an ancient Kannada text written on palm leaves), 10 kg of leaves of three different plant species (*Alangium salvifolium, Anethum sowa*, and *Trigonella foenum-graecum*) were added to the soil around a single *Phyllanthus* tree. Then, fresh fox meat was added and the soil was irrigated daily. KPP recommends that instead of fox meat, the flesh of animals that have died a natural death should be used. *Vetiveria* and *Withania somnifera* roots were used to cover the stem portion and water was sprinkled over this. One kilogram of honey was diluted and applied once a month for three months. The treatment resulted in the tree growing very fast. It yielded 10 times more biomass than surrounding plants (Anand and Aruna Kumara, 1999).

In the Eastern Ghats (India) live about 60 tribal communities with a total population of about 10 million people. Most of these tribes live in hilly, forested areas. Each tribal group has a distinct lifestyle based on its belief in nature and the spiritual world. The tribal people believe in the existence of natural and supernatural divine beings. Everything in their lives is controlled by these divine beings who inhabit their houses, villages, fields, mountains, forests, rivers, and burial grounds. The tribal people also believe in ancestral spirits, who keep a constant vigil over them and render help in times of danger and distress. All spiritual beings are beyond human control. Submission, devotion, and reverence are needed to appease these powers (Gowtham Shankar, 1999).

The tribal communities possess special knowledge of soil conservation and land management. Soil and land selection for various crops requires the skilled knowledge of religious leaders who are able to test soils by colour, weight, and taste and assess the gradation of the land. They know specific plants that arrest soil erosion, how to improve soil fertility and how to use green manure and growth stimulants. They perform rituals related to grain conservation and ensure that individual farmers obey the rules for conserving food grains. Touching, eating or selling grains and vegetables without celebrating the necessary festivals is taboo. Several agricultural practices were written on palm leaves. Knowledge is also preserved in the form of folk-songs, mostly retained by women.

What seems to be missing today is a fusion of the best elements from traditional indigenous knowledge with those from modern scientific and technological advances. Such a fusion can go a long way in enhancing the value of indigenous practices, besides making them more environment-friendly.

INTELLECTUAL PROPERTY RIGHTS AND BIODIVERSITY: THE ECONOMIC MYTHS

The WTO's (World Trade Organization's) Agreement on Trade Related

Aspects of Intellectual Property Rights, or TRIPs, came into effect in 1995 and will have to be fully implemented by developing countries by the year 2000, and by 2005 for less developed countries. Failure to comply will attract trade sanctions.

What are the economic costs and benefits of TRIPs for developing countries and their biodiversity wealth? According to Gaia Foundation and GRAIN (1998), the three myths about intellectual property rights (IPRs) and economic development are the technology transfer myth, the innovation myth, and the investment, including foreign direct investment (FDI), myth. It is feared that the costs of TRIPs may outweigh any benefits for developing countries. Transnational corporations (TNCs) are likely to expand their markets but the South may not attract significant investment or technology transfer. The South may not really experience economic growth because of stronger IPRs. Prices of seeds and medicines will rise and monopoly conditions will constrain national firms. Also, the South's subsidy to the North's R&D can rise. Gaia Foundation and GRAIN have suggested that government and non-government organizations concerned about the impact of TRIPs on developing countries should fight for:

(1) The withdrawal of all obligations to extend IPRs to plant varieties.

(2) A major reassessment of the costs and benefits of TRIPs and the scrapping of the treaty if the negative implications are too costly for the South.

(3) Thwarting the extension of TNC monopolies on biodiversity, such as the UN Convention on Biological Diversity (CBD).

The main argument used by industrialized countries to pressurize developing countries to accept the inclusion of IPRs into the multilateral trade system was that weak IPR protection is a barrier to free trade. During the TRIPs negotiations, patent protection was extended to plants, microorganisms, biotechnological techniques, food, and essential drugs, generating several ethical and legal problems for many developing countries. But it was largely the economic dimensions of IPRs which fuelled the South's opposition to the TRIPs Agreement.

According to Gaia Foundation and GRAIN (1998), the classic argument concerning the relation between intellectual property rights and economic development rests on a number of economic myths.

ECONOMIC ASSUMPTIONS OF TRIPs

Technology is an engine of economic development. Developments in information technology, new materials, and genetic engineering are changing patterns of production across economic sectors. In biotechnology, previously discrete sectors of production and distribution, e.g., seeds, agrochemicals, pharmaceuticals, and food processing, have been integrated.

Since over 40% of production worldwide comes from the exploitation of biodiversity, any technology which changes our productive uses of biodiversity as strongly as genetic engineering and cloning will have a marked impact on developing countries which are the source of some 90% of the world's store of biological resources; in these countries, majority of the poor people lack access to adequate food, environmental security, and health.

Sadly, the technology gap between North and South has been growing. Technology flows to developing countries have declined greatly in the past two decades. It is feared that the strengthening of IPRs may really lead to a freezing out of technology importers in the South.

IPRs, such as patents, supposedly help achieve a balance between the need to offer incentives for research and innovation and the need to protect the broader public interest. IPR systems are supposed to act as catalysts for technology generation but in fact this is not true as there is no clear-cut causal link. The existence of any economic link between IPRs and technology appears doubtful. A patent has no relevance to the health of a given economy, but has a lot to do with the potential for market control conferred on the patent holder, and this is why industrialized countries will continue to use IPRs to artificially freeze their technological leverage in the global economy (Gaia Foundation and GRAIN, 1998).

TECHNOLOGY TRANSFER MYTH

There is no definite evidence about the extent of influence that IPRs exert on technology transfer. The international market for technology is imperfect and current conditions are heavily skewed against those developing countries which desire to have access to new technologies. These countries are usually not attractive recipients for technology transfers because they have fairly weak indigenous technological capabilities. They face a serious dilemma. They are more dependent than ever on TNCs for technology transfer and foreign investment. But they are being frozen out of those flows. The compulsory intellectual property regime of TRIPs has the potential to aggravate this exclusion. The type of patent protection fostered by TRIPs can limit the technological trickle-down that occurs when advanced technology is adapted for developing country markets.

INNOVATION MYTH

There is some debate as to whether the patent system does, or does not have much relevance for innovation. Competition for market share is the biggest influence on R&D investments by firms. The role of patents *vis-a-vis* innovation is not only sector-specific, but differs on a country-to-country basis. Patents are only significant to innovation in some industries, e.g., in pharmaceuticals and chemicals. In the drugs industry, the IPR incentive works to increase prices and lower consumption.

There seem to be two chief flaws in the IPR-innovation link. Much innovation and technology development occur in total absence, or profound uncertainty about the availability, of IPRs, especially in developing countries which have developed the biodiversity that the world depends on for food, medicine, shelter, and clothing without any IPR regimes. Farmers have never treated their germplasm as private property. They have exchanged it freely so that further innovation benefits not only them but also others. The second main fault is the ideological emphasis placed upon IPRs as the preferred incentive system for innovation. In fact, many incentives, e.g., subsidies and tax credits, already exist for innovation.

TRIPs gives the flawed IPR-incentive concept universal applicability. Many fear that the imposition of IPRs on the South will kill or suppress indigenous innovation and their economies.

FOREIGN DIRECT INVESTMENT MYTH

Most trade-related IPR agreements are based on an erroneous understanding of the link between investment and IPR. Liberal economists believe that strong IPR protection is necessary to attract FDI which is the preferred form of external investment today as it provides the long-term promise of stable capital for recipient countries, as opposed to speculative investment or equity portfolios. Industrialized countries account for about 80% of FDI outflows and 60% of FDI inflows. Most FDI going to the South ends up in China (including Hong Kong), South Korea, and Singapore. Most FDI flows occur through mergers and acquisitions.

But any causal link between FDI and economic growth is doubtful. Many studies on the determinants of growth have ignored FDI in their calculations. In reality, liberalization of trade and FDI regimes is leading to recession in newly industrializing economies by disrupting their labour markets and dampening growth.

FDI flows appear to be much more sensitive to changes in short-term economic variables, such as exchange rates, than in long-term policy, such as the availability or strength of IPR. Indeed, even UNCTAD (1997) pointed out that IPR is a relatively unimportant determinant of FDI.

The FDI inflow share of developing countries has gone up while their share in global technology transfer has gone down partly because China, again, is absorbing the greater part of the FDI boom of recent years. This pattern does not correlate with a strengthening of IPR regimes. Neither China nor several other Asian developing countries which attract FDI have evolved IPR systems. Table 9.2 lists some economic arguments for and against strong IPRs in developing countries.

ECONOMIC COSTS OF TRIPs

Any economic analysis of the TRIPs Agreement should cover not only the alleged returns to developing countries but also the costs. That there will

Table 9.2 Economic arguments for and against strong IPR in developing countries (after Gaia Foundation and GRAIN, 1998)

For	Against
It stimulates technology generation which leads to growth and high standards of living	The most important factor in the development of IPRs has not been the expected economic pay-offs on the side of developing countries but political coercion exercised by industrial countries
It stimulates investment	Biotechnology corporations have been spending billions of dollars annually on R&D despite weak and uncertain patent protection in many of the world's largest markets—including the European Union; their biotechnology patenting directive is not even in force and is currently under dispute at the European Court of Justice The profit motive, without IPR props, appears to work well enough alone even in a high-tech, high-risk R&D sector; this shows that there is no correlation between investment and IPR, just as there is no confirmed correlation between investment in R&D and economic growth
It attracts foreign direct investment (FDI)	Most FDI is concentrated in a small number of companies and flows within the different branches of the same company across borders Ten developing countries alone absorb 80% of all FDI flowing to the South; this must be weighed against payment of licences and royalties by all developing countries to foreign IPR holders, which drains precious reserves
It stimulates technology transfer from North to South	An estimated 70% of global payments of royalties and licence fees (direct evidence of technology transfer) relates to transactions between parent TNCs and their foreign affiliates TRIPs treats the importation of patented products or processes by the South as the actual 'working' of a patent in the purchasing country, therefore giving an illusion of technology transfer
It stimulates research and innovation by allowing inventors recoup R&D costs	Relationship between monopolies and innovation is weak IPR essentially puts territorial borders around technologies and other inventions so that firms can capture higher rents (profit maximization)

Table 9.2 Economic arguments for and against strong IPR in developing countries (after Gaia Foundation and GRAIN, 1998) (cont.)

For	Against
	There is no inherent relationship between patents and R&D In developed countries, industry recoups 15–20% of its R&D costs through patents, whereas in a country such as India the figure for a domestic inventor is less than 2%, because Indian invention is usually of an adaptive nature, implying that strong patent rights are not the relevant mechanism to generate profits on R&D expenditure
It is conducive to public benefits of disclosure which outweigh costs of artificial monopolies in the market-place	This is untenable because IPR does not guarantee disclosure Trade secrecy ranks first as a method for protecting innovation in most industries across the US economy, especially in information technologies and biotechnology; in the latter industry, written disclosure has been replaced by physical deposit of samples which are not available to the public Firms avoid disclosure of their patent portfolios Even rejected patent applications are kept secret
It generates technology, an engine of national economic growth	Over 80% of US companies contacted indicated that 'blocking technical areas' with no intention of working the invention was a prime motive for patenting Patents are 'trump cards' to negotiate licences. The patent system regulates competition and does not necessarily stimulate technology generation, much less diffusion
It is essential to free markets	IPR is a market distortion in itself, being a government sanctioned monopoly and a subsidy In open markets, IPR helps regulate competition between firms but does not relieve the market of barriers to trade because it is, by definition, a barrier to trade In the long term, strong IPR system can result in price discriminations depending on demand elasticities Patent pooling, tied up sales, cross licensing, refusal to license, territorial restraints, and many other market-distorting practices are common in countries with strong IPR systems

Table 9.2 Economic arguments for and against strong IPR in developing countries (after Gaia Foundation and GRAIN, 1998) (cont.)

For	Against
It is an indiscriminatory democratic system, subject to full public participation	The opposite is true: it is an expensive elitist system A patent has to be defended by its owner, not the government A typical law suit over one claim of an invention can cost up to $200,000 today in US; patent infringement litigation costs $1 million in US and $600,000 in Europe

be significant returns is doubtful. TNCs will expand their sales of IPR-protected goods and services under a general climate of enhanced IPR enforcement. In the patent area, restrictions on compulsory licensing and treatment of importation as working of patents will encourage the expansion of some markets. However, developing countries may not expect increased or improved basic resources for national development, such as investment, technology transfer, and enhanced local innovation. There are two sets of costs involved in implementing the TRIPs Agreement: the straightforward costs and the hidden costs.

Straightforward Costs of TRIPs

These are obvious and not negligible. TRIPs must be enforced through judicial and administrative systems. The costs of reforming these systems vary from country to country. It is feared that the budgets necessary for reforms at the administrative, judicial, and legal levels will divert national resources from basic socio-economic programmes, especially in the least developed countries. Another direct cost will result from firms—which until TRIPs have been producing infringing goods, such as counterfeit entertainment, clothing, and luxury items—suffering a decline in output. People will lose jobs and national economies will be adversely affected. Domestic pharmaceutical production will decline in developing countries because licence fees and prices will rise. This will be very detrimental. Poor people simply cannot afford expensive medicine, and TRIPs will allow foreign drug companies to not only jack up prices considerably, but also outlaw parallel imports and generic versions of patented drugs (Gaia Foundation and GRAIN, 1998).

Hidden Costs of TRIPs

TRIPs will result in a large number of hidden costs: some direct, some indirect, some explicitly derived from the TRIPs Agreement, and others related to IPR in general. Some major ones include the cost of monopolies, reverse revenue flows from South to North, and erosion of innovation effort in the South.

The review of the economic implications of the TRIPs Agreement for developing countries undertaken by the Gaia Foundation and GRAIN underscores three major messages, viz.:

(1) TRIPs imposes the wrong concept of innovation.

(2) TRIPs encourages dependency only on one incentive—and it is a highly inefficient one.

(3) TRIPs relies on a faulty cost-benefit analysis.

Considering the economic and social aspects, governments, scientists, and public interest groups should work out more promising systems to promote research and development in the South. At the very least:

(1) The obligation to provide any form of intellectual property protection on plant varieties or any other life-form, be it by patent or *sui generis* system, should be withdrawn.

(2) The full-scale review of the entire TRIPs Agreement scheduled for 2000 should invite a very broad assessment of the costs and benefits of the Agreement to developing and least developed countries, and if the conclusion is negative, the treaty should be scrapped. Particular attention should be given to the application of TRIPs to biological diversity and how it will affect the economic resource base, indigenous knowledge, ethics, and the terms of access to scientific information, as well as the control of society's food and medicine.

(3) Any strengthening of IPR regimes should be blocked by other legal instruments related to biodiversity such as the CBD and the FAO Undertaking on Plant Genetic Resources.

PLANETARY MANAGEMENT

As there exist several scientific uncertainties over some global environmental issues, scientists are usually able to do nothing except outline a wide range of possibilities. In contrast, policy makers and politicians prefer to make decisions, especially expensive ones, based on a degree of certainty that is elusive in the face of the complexity of the earth system. This difference in approach is exemplified by the situation regarding future anthropogenic emissions of greenhouse gases: scientific advice on the likely impacts amounts to a variety of possible consequences along with a warning that surprises are likely. It is not surprising that the politically inspired Kyoto Protocol amounts to little more than a tiny step towards limiting climate change (see Parry *et al.*, 1998).

Scientists need to improve understanding of how the earth system functions, with a focus so as to optimize the role of policy makers. Recent interdisciplinary researches have shown that the anticipated carbon sequestration by land vegetation in the twenty-first century is likely to hit a ceiling. The identified limiting factors include the diminishing response of photosynthesis to an increasing burden of atmospheric CO_2, a temperature-driven increase in respiration of plant carbon in soils, and, in systems where vegetation replacement is induced, the slow rate of carbon gain during growth relative to that during vegetation loss (Newton, 1999).

It is quite hard to establish an effective integration framework on a global scale, as present capabilities for modelling the earth system are quite limited. A dual approach is being planned. On the one hand, the rather conventional approach of improving coupled atmosphere-ocean-land-ice models is to be pursued. The computational demands are extreme, as is borne out by the Earth System Simulator—640 linked supercomputers providing 40 teraflops and a cooling system under one roof—to be built in Japan by 2003 (Newton, 1999).

The second course is the development of earth system analysis, for example, that proposed by Schellnhuber and Wenzel (1998), as a hypothesis-testing framework. Such analyses include the social dimension, ultimately aspiring to a mathematical analysis of sustainable development, leading to the idea of a manual for planetary management. A policy-relevant objective might be to develop such models to identify the likely routes of human activities that could lead to intolerable risks to the global environment, so as to chart probable safe courses.

Integration on local to regional scales for problem-solving studies is less difficult. But if a region undergoing environmental change is to be investigated, the strategy from the beginning should involve scientists across such disciplines as the physical and the social, and ecology to economics.

A framework for future studies should emphasize environmental change of relevance to society, at global and regional scales, largely focused on the next two decades and linking the 'hard' sciences to the social. Centred on the earth system as a whole, cross-cutting activities should target themes such as the carbon and water cycles, or ecosystem services (Newton, 1999).

Just half a century ago, forests covered 50 million km^2 or almost 40% of earth's ice-free land. Today, they cover 34 million km^2 at most, and almost half of this is degraded. This is perhaps the biggest land use change to occur on earth in such a short span of time.

We shall pay heavily for what will be eliminated if we allow present exploitation patterns to persist. At the current rate of deforestation, we are likely to see the death of most tropical forests within only a few decades. Further, global warming, with its shifts in temperature and precipitation bands, may well cause an extensive die back of boreal forests.

Forests are fundamental to our biosphere's workings. Tropical forests alone contain over one-half of all species and, because some 160,000 km^2 of them are destroyed every year, they are the site of most extinctions. Some 30,000 plant and animal species out of a planetary spectrum of 10 million become extinct every year.

Even more valuable are forests' environmental services. Forests protect soils with their moisture and nutrients. They also protect watersheds and so regulate water flows. They also regulate rainfall regimes and the albedo effect. They help slow global warming by virtue of their carbon sinks with 1200 gigatons out of 2000 gigatons of carbon in all terrestrial plants and soils. At present high rates of burning, they release perhaps 1.3 gigatons of carbon per year, or one-fifth as much as emitted by combustion of fossil fuels. Conversely, forests act as a strong sink for the atmospheric CO_2. One way to check global warming may be through large-scale reforestation of the humid tropics, where trees grow several times faster than in temperate zones.

Today, forests are some of the least developed of all natural resources. They are still not used in the sustainable ways that could provide both material goods and environmental services, while serving the long-term interests of many communities. Many forests are being exploited for only a few outputs, e.g., timber and agriculture, with adverse consequences for their many other outputs. They are both overexploited and underutilized (Myers, 1999).

According to WCFSD (1999), the decline of forests may change the very character of the planet and the human enterprise within a few years unless we make some choices now. These choices include radical reform, a new political agenda, greater civil society involvement, and more science in policy-making (WCFSD, 1999). The constraint is that forestry policy is not generally set by foresters. Forests are largely eliminated not by overlogging but by agricultural encroachment, industrial pollution, and a variety of other non-forestry factors. There is urgent need for (1) a greater appreciation by governments of the full panoply of forest values, and (2) a more vigorous assertion by foresters of what is at stake for activities and sectors far beyond forests (WCFSD, 1999).

10

HUMAN-SCALE DEVELOPMENT

INTRODUCTION

Human-scale development (HSD) emphasizes the role of human creativity in development and provides a conceptual framework which shows a way out of the useless confrontation between traditional developmentalism and neo-liberal monetarism (McNeely and Pitt, 1985). The purpose of the economy should be to serve the people, and not the people to serve the economy. Keeping this principle in view and on the basis of an in-depth analysis of the nature of human needs, HSD can be a challenging new contribution to development philosophy.

Developmentalism in the 1970s and 1980s was a generator of ideas and of currents of thought and led to the creation of several important institutions in developing areas of the world. In several countries, there were initiatives such as planning agencies, development organizations, industrialization policies, banking reforms, and people's movements. But the creation of important organizations also generated counter-reactions and backlash, so that some existing centres of power in the North argued back but on the defensive. In the decade of the 1970s, this creative energy was slowly contained. Some of the international agencies began to lose their original identity. Neo-liberal monetarism, which had already made sporadic incursions—without managing to impose its character beyond the periods of stability in the economic cycle—began to break forth with all its vigour.

Developmentalism did not fail because of lack of ideas or dearth of creativity. Rather, its contributions in creating a rich and diversified economic structure have been enormous. Its failure was due to its inability to control monetary and financial imbalances; the productive structure—particularly industry—that is generated, which placed a great emphasis on the concentration of resources; and the fact that its approach to development was predominantly economic, thus neglecting other social and political processes that emerged with increasing strength and relevance especially after the triumph of the Cuban Revolution (Max-Neef *et al.*, 1989).

The history of monetarist neo-liberalism is quite different. If developmentalism was a generator of thought, monetarism has tended to be a concocter of prescriptions, at least in some countries. Unlike developmentalism, monetarist neo-liberalism has had disastrous results over a shorter time period. Monetarist neo-liberalism resembles a Phoenician collapse that usually leaves nothing after it but a tremendous void.

From the viewpoint of neo-liberalism, growth is an end in itself and concentration is accepted as a natural consequence. As for developmentalism, growth is an economic condition which will bring about development. Both assume that concentration encourages growth. But neo-liberalism does not see any need whatsoever to check growth whereas developmentalism acknowledges the existence of limitations to growth but fails to control them.

OBJECTIVES

Human-scale development is focused on the satisfaction of basic human needs, on the generation of growing levels of self-reliance, and on the construction of organic articulations of people with nature and technology, of global processes with local activity, of the personal with the social, of planning with autonomy, and of civil society with the state. Here, articulation means a balanced interdependence among given elements.

Human needs, self-reliance, and organic articulations make up the pillars which support HSD. But these pillars have to be sustained on a solid foundation which means the creation of those conditions where people themselves are the protagonists of their future.

These processes which nurture diversity and increase social participation and control over the environment play a crucial role in the articulation of plans to expand national autonomy and distribute the fruits of economic development more equitably. Therefore, it is essential to prevent the increasing atomization of social movements, cultural identities, and communities.

Effective action for the satisfaction of the basic needs of human beings is the major pillar of any development in order to overcome the degrading state of impoverishment which holds many Third World people in its clutches. Development and human needs are undoubtedly irreducible components of a single equation. Proper conditions must be created for a new way of conceptualizing development. This means a substantial modification of the prevailing perceptions about strategies for development. It should be realized that the social and economic theories, which have sustained and directed the processes of development, are both not only incomplete but also inadequate. New and more disquieting frustrations are sure to dominate our increasingly heterogeneous and interdependent world if development models based on mechanistic theories and misleading aggregate indicators are applied.

Human-scale development, geared to meeting human needs, compels us to perceive and assess the world (that is, people and their activities) in a manner which differs completely from the conventional one. There is a strong need for transdisciplinary approaches. Only such an approach can help us to understand, for instance, how politics, economics, and health have converged. Thus, we discover an increasing number of cases where poor health is the outcome of unsound politics and bad economics. If some economic policies designed by economists affect the whole of society, economists can no longer claim that they are solely concerned with the economic field. Such a view would be patently unethical because it would mean avoiding the moral responsibility for the consequences of an action.

The basic postulate of HSD is that development is about people and not about objects.

Traditional indicators, such as the gross national product (GNP) which is an indicator of the quantitative growth of objects, need to be supplemented with some indicator about the qualitative growth of people. The best development process will be one that allows the greatest improvement in people's quality of life. According to traditional beliefs, human needs are infinite, they change all the time, they are different in each culture or environment, and they are different in each historical period. We should like to suggest that such assumptions are inaccurate since they are the product of a conceptual shortcoming. But needs should not be confused with satisfiers. Human needs must be understood as a system, that is, they are all interrelated and interactive. Except for the need of subsistence (to remain alive), no hierarchies exist within the system. On the contrary, simultaneities, complementarities, and trade-offs are characteristics of the process of needs satisfaction (Max-Neef *et al.*, 1989).

NEEDS AND SATISFIERS

Table 10.1 is a matrix of needs and satisfiers. There is no one-to-one correspondence between needs and satisfiers. A satisfier may contribute simultaneously to the satisfaction of different needs or, conversely, a need may require different satisfiers in order to be met. Two other important postulates are (1) fundamental human needs are finite, few, and classifiable; and (2) fundamental human needs (such as those contained in the system proposed) are the same in all cultures and in all historical periods. What does change, both over time and through cultures, is the manner or the means by which the needs are satisfied.

What is culturally determined are not the fundamental human needs, but the satisfiers for those needs. Cultural change is, among other things, the consequence of dropping traditional satisfiers for the purpose of adopting new or different ones (Max-Neef *et al.*, 1989).

One important challenge confronting the Third World consists of recognizing and assessing the collective pathologies generated by diverse sociopolitical systems. Every system creates in its own way obstacles to the satisfaction of one or more needs such as understanding, protection, identity, affection, creation, and freedom. Any fundamental human need not adequately satisfied generates a pathology. Hitherto, we have developed only treatments for individual and small group pathologies. But now we are faced with a dramatic increase in collective pathologies for which no effective treatments exist. These collective pathologies can be understood only through transdisciplinary research and action (Max-Neef *et al.*, 1989).

For defining and assessing any environment in the light of human needs, it is necessary to analyze the extent to which the environment re-

Table 10.1 Matrix of needs and satisfiers* (after Max-Neef *et al.*, 1989)

Needs according to existential categories Needs according to axiological categories	Being	Having	Doing	Interacting
Subsistence	1/ Physical health, mental health, equilibrium, sense of humour, adaptability	2/ Food, shelter, work	3/ Feed, procreate, rest, work	4/ Living environment, social setting
Protection	5/ Care, adaptability, autonomy, equilibrium, solidarity	6/ Insurance systems, savings, social security, health systems, rights, family, work	7/ Cooperate, prevent, plan, take care of, cure, help	8/ Living space, social environment, dwelling
Affection	9/ Self-esteem, solidarity, respect, tolerance, generosity, receptiveness, passion, determination, sensuality, sense of humour	10/ Friendships, family, partnerships, relationships with nature	11/ Make love, caress, express emotions, share, take care of, cultivate, appreciate	12/ Privacy, intimacy, home, spaces of togetherness
Understanding	13/ Critical conscience, receptiveness, curiosity, astonishment, discipline, intuition, rationality	14/ Literature, teachers, method, educational policies, communication policies	15/ Investigate, study, experiment, educate, analyze, meditate	16/ Settings of formative interaction, schools, universities, academies, groups, communities, family
Participation	17/ Adaptability, receptiveness, solidarity, willingness, determination, dedication, respect, passion, sense of humour	18/ Rights, responsibilities, duties, privileges, work	19/ Become affiliated, cooperate, propose, share, dissent, obey, interact, agree on, express opinions	20/ Settings of participative interaction, parties, associations, churches, communities, neighbourhoods, family

Table 10.1 Matrix of needs and satisfiers* (after Max-Neef *et al.*, 1989) (cont.)

Needs according to existential categories / Needs according to axiological categories	Being	Having	Doing	Interacting
Idleness	21/ Curiosity, receptiveness, imagination, recklessness, sense of humour, tranquillity, sensuality	22/ Games, spectacles, clubs, parties, peace of mind	23/ Day-dream, brood, dream, recall old times, give way to fantasies, remember, relax, have fun, play	24/ Privacy, intimacy, spaces of closeness, free time, surroundings, landscapes
Creation	25/ Passion, determination, intuition, imagination, boldness, rationality, autonomy, inventiveness, curiosity	26/ Abilities, skills, method, work	27/ Work, invent, build, design, compose, interpret	28/ Productive and feedback settings, workshops, cultural groups, audiences, spaces for expression, temporal freedom
Identity	29/ Sense of belonging, consistency, differentiation, self-esteem, assertiveness	30/ Symbols, language, religion, habits, customs, reference groups, sexuality, values, norms, historical memory, work	31/ Commit oneself, integrate oneself, confront, decide on, get to know oneself, recognize oneself, actualize oneself, grow	32/ Social rhythms, everyday settings, settings which one belongs to, maturation stages
Freedom	33/ Autonomy, self-esteem, determination, passion, assertiveness, open-mindedness, boldness, rebelliousness, tolerance	34/ Equal rights	35/ Dissent, choose, be different from, run risks, develop awareness, commit oneself, disobey	36/ Temporal/spatial plasticity

*The column of BEING registers *attributes*, personal or collective, that are expressed as nouns. The column of HAVING registers *institutions*, *norms*, *mechanisms*, *tools* (not in a material sense), *laws*, etc. that can be expressed in one or more words. The column of DOING registers *actions*, personal or collective, that can be expressed as verbs. The column of INTERACTING registers *locations and milieus* (as times and spaces). It stands for the Spanish ESTAR or the German BEFINDEN, in the sense of time and space. Since there is no corresponding word in English, INTERACTING was chosen 'á faut de mieux'.

presses, tolerates or stimulates opportunities. How accessible, creative or flexible is that environment? How far can people influence the structures that affect their opportunities? It is the satisfiers which define the prevailing mode that a culture or a society ascribes to needs. Satisfiers are not the available economic goods. They are related, instead, to everything which, by virtue of representing forms of being, having, doing, and interacting, contributes to the materialization of human needs. Satisfiers include, *inter alia*, forms of organization, political structures, social practices, subjective conditions, values and norms, spaces, contexts, modes, types of behaviour, and attitudes (Max-Neef *et al.*, 1989).

The interrelationship between needs, satisfiers, and economic goods is permanent and dynamic. While economic goods can affect the efficiency of the satisfiers, the latter help generate and create the former. Through this reciprocal causation, they become both part and definition of a culture which, in turn, delimits the manner of development (see Table 10.2). A look at the different squares in the matrix (Table 10.1) with their possible satisfiers brings out clearly that many of the satisfiers can give rise to different economic goods.

Because satisfiers have various characteristics, several types can be suggested for analytical purposes, e.g., (1) violators or destroyers, (2) pseudosatisfiers, (3) inhibiting satisfiers, (4) singular satisfiers, and (5) synergic satisfiers (see Tables 10.3 to 10.6) (Max-Neef *et al.*, 1989).

Development for the satisfaction of fundamental human needs cannot be structured from the top downwards. Nor can it be imposed by law or by decree. It can come only directly from the actions, expectations, and creative and critical awareness of the protagonists themselves. People at large must take a leading role in development. The state can only assume a role which encourages synergic processes at the local, regional, and national levels. Regaining diversity may be the best way to encourage the creative and synergic potential which exists in every society. The harmonious coexistence of different styles of regional development needs to be accepted sincerely within the same country, instead of insisting that 'national styles' should prevail, when these have so far proved to be instrumental in increasing the affluence of some regions at the expense of the impoverishment of others.

ETHNIC DIVERSITY

Humankind is now facing a growing social crisis and polarization is rising everywhere. Globally, the ratio of the income of the top 20% of the population to that of the bottom 20% increased from 30 : 1 in 1960 to 78 : 1 in 1994. Extreme poverty or misery afflicts the poor people in many countries, some of whom are turning to crime as they have little choice. An urgent reintegration of social development and economic growth in the information age requiring much technological upgrading of countries, firms, and households around the world is the need of the hour.

Table 10.2 Violators or destructors* (in all cases, protection is the need to be satisfied)

Supposed satisfier violator impairs	Needs whose satisfaction is affected
Arms race	Subsistence, affection, participation, freedom
Exile	Affection, participation, identity, freedom
National security doctrine	Subsistence, identity, affection, understanding, participation, freedom
Censorship	Understanding, participation, leisure, creation, identity, freedom
Bureaucracy	Understanding, affection, participation, creation, identity, freedom
Authoritarianism	Affection, understanding, participation, creation, identity, freedom

*Violators or destructors are elements of a paradoxical effect. Applied under the pretext of satisfying a given need, they not only annihilate the possibility of its satisfaction, but they also render the adequate satisfaction of other needs impossible. They seem to be especially related to the need for protection.

Table 10.3 Some pseudosatisfiers*

Satisfier	Need which it (apparently) satisfies
Overexploitation of natural resources	Subsistence
Formal democracy	Participation
Aggregate economic indicators	Understanding
Cultural control	Creation
Status symbols	Identity
Indoctrination	Understanding
Charity	Subsistence
Fashions and fads	Identity

*Pseudosatisfiers are elements which stimulate a false sense of satisfying a given need. Though they lack the aggressiveness of violators, they may, on occasion, annul, in the medium term, the possibility of satisfying the need they were originally aimed at.

Recent years have seen increasing conflicts among different ethnic, racial, and religious groups. Young (1998) drew attention to policy alternatives that can contribute to the alleviation of ethnic conflict and the accommodation of cultural diversity. He edited and compiled several different policy experiences in the areas of decentralization and federalism, ethnic preference, electoral systems, education, immigration, and indigenous peoples, and suggested that governments must avoid the illusion of solving ethnic questions in 'permanent' ways. Successful policies are those

Table 10.4 Some inhibiting satisfiers*

Satisfier	Need	Needs whose satisfaction is inhibited
Paternalism	Protection	Understanding, participation, freedom, identity
Authoritarian classroom	Understanding	Participation, creation, identity, freedom
Unlimited permissiveness	Freedom	Protection, affection, identity, participation
Obsessive economic competitiveness	Freedom	Subsistence, protection, affection, participation, leisure
Commercial television	Leisure	Understanding, creation, identity

***Inhibiting satisfiers are those which, by the way in which they satisfy a given need, seriously impair the possibility of satisfying other needs.**

Table 10.5 Some singular satisfiers* (after Max-Neef *et al.*, 1989)

Satisfier	Need which it satisfies
Programmes to provide food or housing	Subsistence
Curative medicine	Subsistence
Insurance	Protection
Ballot	Participation
Guided tours	Leisure
Gifts	Affection

***Singular satisfiers are those which aim at the satisfaction of a single need and are, therefore, neutral as regards the satisfaction of other needs. They are very characteristic of development and cooperation schemes.**

that evolve and adapt, remaining relevant through changes in societies and relationships among the diverse groups that comprise them. Concentrating efforts on building a civil community, in which core values are shared by all ethnic groups, is the best approach to building a durable framework for accommodating diversity (see Young, 1998).

EXCESSIVE MATERIALISM

Today, considerable emphasis is placed on monetary worth as the principal determinant of value for individuals and societies. The dominant modern culture has endowed money—both in itself and as a source of consumption, possession, and power—with all the great virtues. Signs of this cult can be seen everywhere: the status of economic indicators in the definition of a country's overall performance; the division of the world into

Table 10.6 Some synergic satisfiers* (after Max-Neef *et al.*, 1989)

Satisfier	Need	Needs whose satisfaction it stimulates
Self-managed production	Subsistence	Understanding, participation, creation, identity, freedom
Popular education	Understanding	Protection, participation, creation, identity, freedom
Democratic community organizations	Participation	Protection, affection, leisure, creation, identity, freedom
Barefoot medicine	Protection	Subsistence, understanding, participation
Democratic trade unions	Protection	Understanding, participation, identity
Preventive medicine	Protection	Understanding, participation, subsistence
Meditation	Understanding	Leisure, creation, identity

*Synergic satisfiers are those which, by the way in which they satisfy a given need, stimulate and contribute to the simultaneous satisfaction of other needs.

developed and developing regions; the global spread of capitalism; the liking and preference of everything private and the contempt for everything public; the monetization of most social relations and spheres of life—and, above all, the common reference to money when assessing the success and self-esteem of any individual (Baudot, 1999).

This excessive materialism is rooted in western culture but has an all-pervasive global influence. It marks the emergence of a world market society and makes impossible the fulfilment of the social objectives endorsed by most members of the international community: the elimination of poverty, the reduction of inequalities, and the construction or preservation of integrated and harmonious societies.

Within the basic premises of the market economy, the value placed on human economic initiatives appears to be more critical today than the right to private property. The propagation of the basic principles of the market economy may provide many people with the minimum economic requisites of survival. Hence, absolute poverty may decline worldwide in the coming decades. However, this optimistic view is based on the assumption that environmental degradation will be halted, depletion of natural resources controlled, and human ingenuity activated to develop new techniques and novel products for sustaining a larger world population (Baudot, 1999).

Beyond the satisfaction of basic needs, the reduction of relative poverty is highly problematic. Poverty means a life of deprivation in comparison with the lifestyles of the middle and upper classes. Global capitalism sets higher and higher living standards while simultaneously reflecting patterns of production and consumption that are unsustainable even in the medium term. No doubt, redistribution of income and resources among social groups and countries is eminently desirable, but it would not suffice to reduce relative poverty. Only a strong change of what makes a good life toward more frugality and more spirituality would be the right move. Poverty is growing with materialism and egoism.

POVERTY

Poverty may be defined as a state of deprivation with reference to socially-accepted norms and standards of basic human needs. Poverty is widespread in developing countries, both in rural and urban areas. A common scenario of rural poverty in a less developed country may be described as follows. In the morning, a poor farmer harnesses two bullocks to plough the field, his wife pounds the grain she will use for the day's main meal. A few kilometres away, their children are busy collecting fuelwood and water before starting their morning walk to school. The children also often help their mother light a fire with a few sticks, milk the cow, and collect the sundried grain. That evening, as the family rests around the hearth, the father worries about how to sell his onions before sleeping, his wife prepares a basket of home-grown vegetables to sell next day at the market some kilometres away. With the earnings, she might buy a kerosene lamp, although she might not have enough cash left to buy the kerosene immediately.

That description of rural life is a daily reality for hundreds of millions of families throughout the developing world. Rural poverty means subsistence on the meagre earnings of wage labour or unreliable harvests from small plots of land. It means raising a family without safe drinking water or proper sanitation, also suffering disease or injury without medical help. In times of unemployment or crop failure, it means living with the pangs of hunger and the risk of death by famine.

The victims of rural poverty number close to 1000 million, or almost 20% of the world's total population (Table 10.7). In 1988, the rural poor constituted about 35% of the total rural population and 80% of the total poor (Jazairy *et al.*, 1992). The proportion of the rural population whose income and consumption fell below nationally-defined poverty lines was estimated at 30% in Asia (or 45% excluding China and India), 60% in Latin America and the Caribbean, and 25% in the Near East and North Africa (Jazairy *et al.*, 1992).

In Latin America/Caribbean, it is the urban poverty which has reached alarming proportions, but the largest numbers of people living in utter destitution were still found in rural areas. In 42 least developed countries, as many as seven in 10 of the rural population were poor (Jazairy *et al.*, 1992). There had been some progress in several developing countries in reducing the percentage of the rural poor population, but the absolute numbers of rural poor had actually increased in the 1980s.

Table 10.7 Rural poverty in some selected countries (after Anonymous, 1994)

Country	Total population (1991)	GNP per capita (1990) ($)	Rural population (1991)	Rural poor (1988) (% of rural population)	Rural population having access to services (1987–90) (%)		
					Health	Water	Sanitation
Botswana	1.3	2230	0.9	55		19	20
Central African Republic	3.1	390	7.6	9.1		11	9
Ethiopia	52.8	120	45.9	43		11	7
Ghana	15.3	390	10.3	54		39	15
Kenya	25.0	370	19.0	55		21	39
Mali	8.7	280	7.0	60		36	5
Mauritius	1.1	2310	0.6	12	100	100	96
Niger	7.9	310	6.3	35	17	52	3
Nigeria	99.0	290	64.3	51	62	20	5
Somalia	8.0	120	5.1	70	15	55	5
Tanzania	25.2	110	16.9	60	73	46	77
Zambia	8.3	420	4.1	80	50	43	34
Afghanistan	20.9		17.1	60	45	17	
Bangladesh	110.6	210	92.9	86			4
Bhutan	1.5	190	1.4	90		30	7
China	1149.5	370	770.1	14		68	81
India	866.5	360	632.5	42		73	4
Indonesia	181.3	560	125.1	27		32	45
Iran	57.7	2490	24.8	30	70	75	35
Malaysia	18.2	2330	10.3	22		66	94

Table 10.7 Rural poverty in some selected countries (after Anonymous, 1994) (cont.)

Country	Total population (1991)	GNP per capita (1990) ($)	Rural population (1991)	Rural poor (1988) (% of rural population)	Rural population having access to services (1987–90) (%)		
					Health	Water	Sanitation
Myanmar	42.7		32.0	40		29	34
Nepal	19.4	180	17.5	61		34	3
Pakistan	115.8	400	78.7	29	50	35	8
The Philippines	62.9	730	36.0	64		72	63
Sri Lanka	17.2	470	13.6	46		55	45
Thailand	57.2	1420	44.0	34			86
Vietnam	67.6		52.7	60		33	
Algeria	25.7	2330	12.3	25	80	55	40
Egypt	53.6	610	28.4	25	99	82	34
Iraq	18.5		5.4	30	96	72	18
Lebanon	3.7		0.6	15			18
Syrian Arab Republic	12.5	1000	6.2	54	99	68	55
Argentina	32.7	2380	4.5	20			29
Brazil	151.4	2680	37.8	73		86	48
Chile	13.4	1950	1.9	56		21	6
Cuba	10.7		2.7	35	100		
Mexico	83.3	2490	22.5	51		49	12
Uruguay	3.1	2620	0.4	29		27	
Venezuela	19.8	2560	1.8	58		89	70

Population figures are in millions. All figures are estimates.

According to World Bank (1993), the number of poor people in the Near East and North Africa and in Latin America and the Caribbean increased by more than the rate of population growth during the 1980s. The proportion of the population considered poor in Sub-Saharan Africa is now almost equal to that in South Asia (World Bank, 1993a).

The World Bank's poverty gap index, which measures how far the average poor person's income is from the poverty line, shows that in Latin America and the Caribbean, the Near East/North Africa and Sub-Saharan Africa, the poor have become poorer. While a slightly higher percentage of the population lives in poverty in South Asia, the depth of their poverty is less than in Sub-Saharan Africa.

The differing performances of the developing regions in reducing poverty are strongly associated with economic growth. During the 1980s, only Asia and the Pacific achieved rates of growth in consumption that were enough to bring down the number of poor.

According to World Bank (1993a), if the current rate of increase in poverty is maintained during the 1990s, about 1300 million people will be living in poverty by the year 2000. Reversing this trend will require both appreciably higher economic growth rates for the rest of the decade and improved patterns of growth. The Bank's projections indicate that Asia/Pacific and Latin America/Caribbean will achieve appreciably more growth than the estimated minimum needed for the number of poor to fall.

CAUSES OF RURAL POVERTY

Rural poverty is created and perpetuated by several interlinked socio-economic aspects that are common to most developing countries. These are briefly outlined here:

(1) Policies and institutional arrangements biased against the poor exclude them from the benefits of development, frustrate their productive potential, and accentuate the impact of other poverty processes.

(2) Persistence, in most of the developing world, of dualistic agrarian structures originating in colonial times.

Side by side with modern agriculture, millions of marginal farmers and herdsmen subsist far below the poverty line. This dualism severely limits their capacity to grow food and accumulate capital. They lack marketable surpluses, and incentives and opportunities to save and invest.

(3) Rapid population growth increases pressure on limited productive resources, social services, and employment as well as—paradoxically—creates labour shortages through migration to urban areas.

The most obvious consequence of rapid population growth is that, even with relatively high rates of economic growth, improvements in living conditions are limited.

(4) Rural poverty, malnutrition, and undernutrition are closely linked to environmental degradation. Throughout the developing world,

poor people in marginal areas are destroying natural resources in their struggle to keep their production systems sustainable.

Degradation of the environment is strongly linked to household food insecurity and lack of fuel. In some cases, government policies have also inflicted severe environmental damage. A rapid expansion of areas under export crops often accelerates deforestation and land degradation. Programmes to expand cereal production into marginal areas, subsidized capital to support commercial operations, subsidies for inappropriate technologies, and excessive transfer of income out of the agricultural sector often undermine the sustainability of smallholders and pastoralists' production systems.

(5) Middlemen and landlords exploit sharecroppers and tenants. Moneylenders exploit debtors, and traders exploit small-scale producers. During seasonal food shortages, the poor often have to borrow money at high interest rates. Forced to devote most of their energies to debt-servicing, they sink deeper and deeper into the poverty trap.

(6) Political troubles and civil strife have a disastrous impact on the rural poor in some countries, e.g., Afghanistan.

The international economic environment directly influences the well-being of the poor. Falling commodity prices and protectionist policies in developed countries affect the employment and incomes of plantation workers and smallholders producing for export, particularly in countries relying heavily on a few agricultural commodities.

The net flow of development resources to agriculture also affects rural poverty. Also, concern with trade balances is diverting resources to export crops, sometimes at the expense of traditional crops grown by poor farmers (FAO, 1993).

The World Summit for Social Development held in March 1995 in Copenhagen recognized the growing seriousness of poverty, unemployment, and social disintegration and endorsed an ambitious and comprehensive action programme to address these problems. The following initiatives were taken thereafter:

(1) financing social development;
(2) promoting democratization and public sector reform;
(3) mainstreaming gender in public policy;
(4) strengthening civil society organization; and
(5) integrating concepts of people-centred sustainable development in planning and project implementation.

Urgent action to improve the international economic environment should be the top priority for strengthening the context in which social development can be promoted and financed. The current financial and trade regime is neither adequate for generating the required level of resources in many countries nor for permitting their rational long-term use.

Considerable effort has been invested in the past few years to design novel ways of organizing and delivering social services, so that even existing resources can be used more efficiently.

Successful democratization and social development should rest on strong foundations that defend basic rules of contestation and protect disadvantaged groups and communities. However, the 1990s have witnessed a decline in state capacity in many developing and transition societies. In ethnically-segmented countries, good institutions need to be established that respect democratic rules of electoral competition, while also generating broad support among contending groups and parties. The failure of democratization to produce such institutions has led many countries in the 1990s to crises of insecurity, civil strife, and war.

POVERTY AND ENVIRONMENT

Poverty is often referred to as a cause of environmental degradation. But one of the greatest threats to the global environment is the rich world. The industrialized countries' patterns of production, transport, and consumption could not be applied throughout the world without plunging our planet into ecological disasters.

Global inequality is both a necessary condition for and a result of the wealthy world's exploitation of developing country resources. For five hundred years, the North has milked the less developed countries, while the latter have received a certain amount of financial assistance and help in developing their administrative systems (Hanneberg, 1992). The North has given something with one hand but has taken away something with the other.

The same colonial pattern can still be seen. Exports at 'bargain' prices flow constantly from South to North: timber from shrinking rain forests, exotic fruits and other crops, medicinal plants, minerals, and fossil fuels, and millions of tons of fish caught in tropical seas.

Movements in the opposite direction are also frequently guided by a search for profits in the industrial nations. Wastes, biocides, and entire industrial complexes that are hazardous to health and the environment end up in developing countries, where laws are laxer.

Both exports to and imports from the rich world, therefore, have long been a cause of ecological decline in the less developed countries. They leave a trail of clear-felled forests, poisoned soils, eroded landscapes, and overfished waters, and ultimately further exacerbate poverty (Hanneberg, 1992). Of course, to some extent, these destructive activities are also compensated for by transfers of development assistance from the industrialized world, in the form of know-how and financial support.

Overpopulation and poverty in the poor countries and also ignorance and greed lead to overexploitation of natural resources.

The need for firewood for cooking and heating accelerates deforestation, grazing by cattle leads to soil erosion, lack of knowledge may result in inappropriate farming methods, overuse of chemical pesticides, inadequate waste management or damage to scarce water resources.

The developing nations have the right to use their natural resources, but the right also entails a responsibility to manage them sustainably and not to sell them off to profit-seeking companies in the industrial countries in such a way that their own land is laid waste. According to Mats Segnestam of Sweden's development agency SIDA, "Poverty is both a consequence of environmental degradation and a cause of it, a vicious circle from which it is difficult to escape. The lifestyle of the developed countries needs to become more restrained, we need to close the gap between rich and poor, and to focus more vigorously on the environment in development cooperation. Otherwise the global environmental crisis will escalate into a far more serious threat."

Sustainable development is a crucial concept, entailing certain principles that apply universally. But tangible solutions may look quite different, depending on the geographical area and the sector concerned. In the final analysis, sustainable development has to be defined in the light of local conditions.

Sustainability is dependent on there being no depletion of the total natural capital; if possible, it should be increased. The following five conditions must be met if this objective is to be achieved in practice:

(1) Human activities must be kept within the framework defined by the necessity of maintaining the remaining natural capital.

(2) Technological development must be synonymous with greater efficiency, rather than increased throughput of raw materials.

(3) Renewable natural resources must not be extracted faster than they are replenished (i.e., we must live on the interest, not the capital).

(4) Pollutant emissions must not exceed what nature can cope with.

(5) Non-renewable resources may be exploited, but only on such a scale that their replacement is ensured by the formation of renewable resources.

POVERTY AND GENDER

Interlinkages between gender and poverty had, until recently, not been carefully scrutinized. At one level, the relationship between gender disadvantage and poverty appears to be quite straightforward; women seem to suffer more from poverty than men in numbers and in intensity. Quite often, social and economic indicators are used to illustrate poverty outcomes. An exclusive focus on poverty outcomes, however, often means that the processes leading to poverty are either overlooked or otherwise analyzed using a few variables abstracted from a far more complex social context (Razavi, 1998). According to Razavi, the gender analysis of poverty is not so much about whether women suffer more from poverty than men, but rather about how gender differentiates the social processes leading to poverty, and the escape routes out of destitution. An understanding of the causal processes leading to poverty has important policy implications: it raises questions about whether it can be assumed, as is often done, that the kinds of policies that can strengthen the position of poor men will have much the same impact on poor women.

Development is based not only on economic growth, but also on the achievement of social goals, including gender equity. Reliable indicators of gender differences in well-being are thus essential. Saith and Harriss-White (1998) examined the gender sensitivity of health, nutrition, and education indicators, as well as that of some composite indices, with reference to developing countries. According to them, assessing single dimensions of well-being may give a false impression of equality if inequality exists in other, unexamined dimensions. The ratio of males to females in the age groups of 0–4 yr and 5–9 yr, which reflects mortality rates in these age groups, was found to be a more suitable indicator of relative female health than the widely used male and female life expectancy at birth. Difficulties with data collection and interpretation reduce the reliability of indicators of nutrition and morbidity. In addition, it appears that gender inequality in well-being may not necessarily be any higher among low income groups, except in the case of education. According to these authors, greater importance needs to be given to improving collection of gender-disaggregated data in national censuses, especially for differing levels of income. Providing policy makers with the results of research on the types of social processes that can result in gender differentials in well-being is also important if indicators are to be used effectively in policy-making (Saith and Harriss-White, 1998).

Employment is crucial to current understandings of poverty and well-being, as well as to prescriptions for poverty reduction. Labour-intensive growth and greater labour force participation by women are highly desirable. But gender analysts paint a complex picture of women and work, noting that women often face social and ideological constraints when seeking, obtaining, and performing work outside households. And the objective of increasing female employment can, in the context of long working days and household chores, lead to what has been termed "time famine" and adverse effects on women's health and well-being (Jackson and Palmer-Jones, 1998).

But the development discourse in general, and poverty and gender debates in particular, often treat labour more as an abstract category than as a physical experience. Yet an analysis of varying levels of energy spent in performing different tasks, as this is related to individual physical strength, shows that women and men have different capacities for physical effort at different stages in their life cycles, both biological differences and socio-cultural norms being significant in this context.

Focusing on the relation between well-being and the arduousness of work, Jackson and Palmer-Jones (1998) considered the implications of a number of poverty eradication policies for the well-being of the poor. They looked, in particular, at agricultural extensification, effort-intensive growth, certain environmentally-friendly and sustainable technologies, and self-targeting through the labour test—a component of food-for-work programmes in which employment is offered to people at such low levels of remuneration that the non-poor do not compete for jobs. And they asked why, when people throughout the world attempt to improve well-being through avoiding heavy physical labour; poverty alleviation strategies do not concentrate more systematically on generating acceptable returns for lower levels of human energy expenditure.

Ghosh (1998) reviewed the manner in which macroeconomic strategies affect the incidence of poverty, especially among women, and the effectiveness of various forms of government intervention in counteracting poverty in India. According to her, the most important reason for the decline in poverty within India during the 1980s was an increase in the real wages of unskilled labour in both urban and rural areas. This was associated with the direct employment generation and multiplier effects of increased government expenditure throughout the decade. Similarly, the deceleration in such expenditure, and the sharp increase in food prices in the aftermath of structural adjustment policies implemented in the 1990s, reversed some gains of the previous decade. Ghosh showed that generalized policies of macroeconomic contraction associated with stabilization measures can worsen the conditions of poorer groups. She stressed the need to rethink policies (often including trade liberalization and the encouragement of agricultural exports) that increase the relative price of food. Any macroeconomic strategy intended to reduce the incidence of poverty must consciously address these problems. The Indian Government has important poverty alleviation programmes, including the public distribution system for food grain, self-employment schemes (such as credit provision for asset-building), and wage employment schemes, all of which affect poor women significantly.

SUSTAINABLE PROSPERITY

A century ago, the average middle class families in urban areas could easily obtain domestic servants and household help. But this has become virtually impossible now, largely as a consequence of two revolutionary transformations that have occurred in many advanced countries and even several developing countries. One of these changes has been that work done utilizing human and animal energy sources some decades ago has given way to the widespread dependence on machines, usually powered by the combustion of coal, oil or gas. The other transformation has been the use of these machines for the mass production of goods to be available and utilized by the population as a whole. In the agricultural area, the advent of machines has often led to the gradual consolidation of small farms into larger, agricultural businesses that can produce far more usable products than the sum of the small farms, and that too by employing a much smaller number of workers. A large fraction of the farm-working populace has switched over to the machine production of non-agricultural goods, such as automobiles, electronics, and plastics; all this made the later part of the twentieth century so different from the later part of the nineteenth century. In some countries, the improvement and expansion in sanitary health practices have greatly increased human life expectancy. Similar related transformations have brought prosperity to a larger fraction of a nation's population than had prevailed in previous centuries.

Taken together, these foregoing tendencies have, with few exceptions, been viewed as almost entirely positive and worth emulation. But unfortunately, the environmental aspects were largely ignored during the first half of the twentieth century. The adverse consequences of the widespread utilization of fossil and other energies, leading to massive use of other resources, and production of the large amounts of waste by-products during the manufacture, use, and throwing away of the newly-available attractive commodities, were not foreseen. The negative consequences started accumulating locally and regionally and some have spread globally. Had some of the problems been tackled early, they could have been controlled but in the mad rush toward development and prosperity, their solutions came to be deferred or shelved. Smog started appearing regularly in the air of large cities, and many lakes and rivers became more and more polluted. The ozone layer started eroding in the upper atmosphere but building up near ground level, producing a situation of double jeopardy. Nevertheless, mankind now has the capability to intervene significantly in the environment on a global scale. The stratospheric ozone depletion problem arose out of scientific efforts to make refrigeration more widely available, was discovered and understood through extensive scientific work, and the proposed solutions were validated through additional scientific and technological work. However, the 1987 Montreal Protocol serves primarily to place a cap upon the total amount of organochlorine and organobromine compounds which will rise to the stratosphere in the coming decades. The Protocol cannot undo the damage which is being done, and will continue in the future, by the long-lived molecules already released to the atmosphere.

Both stratospheric ozone depletion and global warming are global-scale problems with time scales of several decades. The general expectation with each is a relatively steady change, responding to the steady increase in trace gas concentrations, but the rapid onset in the decade of the 1980s of the major ozone losses in Antarctica has been the culmination of the unpleasant surprises which sometimes occur in a not-well-understood system; this suggests that prevention is especially important when dealing with potential changes which have century-long persistence times. Besides these global changes, major transnational regional changes have been recorded as the companion effects for increased desertification and from acid rain. The combination of ever-increasing populations with the desires of all people for better health and greater prosperity is exerting severe strain on the capacity of the global system to react and absorb the changes.

However, for most people of the world, the really critical problems are much more local—availability of clean air and water, efficient disposal of wastes, an energy source for cooking, sufficient clothing and shelter, and access to health care and education. While the atmospheric problems and biodiversity have large basic scientific components and several gaps in knowledge, the local environmental problems are rarely intensively scientific in nature and their solutions are already well-known, but the technological application of this knowledge often cannot be made in particular situations simply because the costs involved are high. In most developing countries, the people are still struggling with the first-order problems of everyday living—problems to which solutions are already known but have not been fully implemented.

Since uncontrolled human actions have wrought serious and unexpected damage to global environment, environment-friendly sustainable development on a global scale is likely to be the single most challenging human concern in the twenty-first century.

Many developing countries have been attempting to provide a better quality of life to their people. But each country has had a different and complex context from which to take off: some started with major handicaps, some had leadership with foresight, some had bountiful natural resources, and others have to contend with autocratic rule or internal strifes. We now have a world scenario in which there exist wide disparities and variations among the developing countries with a few on a take off course for industrial development, some still undeveloped, and the rest falling somewhere in between. Notwithstanding such wide differences, there is no longer any doubt that science and technology are essential instruments for national development.

Earlier, scientific studies were by and large focused on disciplinary topics—how to probe deeper and deeper into smaller and narrower subjects used to pose a serious challenge for the scientist. It is only recently that the need to study and understand highly complex systems and phenomena has been appreciated and deemed to be very important. One very important and complicated system that has attracted attention has been the earth system comprising the land, sea, atmosphere, biosphere, and human activities. This makes an interdependent, interconnected, feedback system that can be properly studied by the application of modelling approaches and by teams of multidisciplinary experts and specialists. Special attention needs to be given also to complex systems having important human dimensions, as there exist several situations where socio-cultural factors may significantly influence the success or failure of future corrective steps. Of course, to incorporate these dimensions into modelling of complex systems is even more difficult and demanding.

PEOPLE-CENTRED SUSTAINABLE DEVELOPMENT

There exist several widely differing views on how to meet the needs of the present without compromising the ability of future generations to meet their own needs. But most people agree that sustainable development implies a better integration of economic, environmental, and social goals. It particularly supports a pattern of economic growth that does not result in widespread environmental degradation or social exclusion. In practice, however, the general tendency has been to equate sustainable development much more narrowly with environmental protection or ecoefficiency. Conservation and rehabilitation of natural resources have become ways to either stretch the limits of economic growth, by using natural resources more efficiently, or protect nature by creating national parks and reserves. In this process, the idea of meeting the needs of people—the idea that is central to the concept of sustainable development—seems secondary.

In recent years, the link between conservation and human welfare appears to have been rediscovered—the United Nations Development Programme has strongly promoted the concept of sustainable human development. Also, the 1995 Copenhagen Social Summit advocated the idea of preserving the essential bases of people-centred sustainable development. But despite several efforts, have people really been brought back into the equation? Have the social and political dimensions of sustainable development achieved the same status as those associated with economic growth and environmental protection?

It has been a common observation that people do not support those environmental projects and programmes which are perceived to threaten their livelihoods and rights. Yet some projects do precisely this by restricting people's access to land, forest products, and water resources. A wide gap separates the rhetoric and reality of people-centred approaches. Although many projects include explicit social components, such as small income-generating activities, these often prove unsustainable once the funding agency withdraws. Such interventions do little to promote human welfare or alter the way people use or manage natural resources. When projects fail to address both environmental and human welfare concerns, people's livelihoods and rights can be threatened (Anonymous, 1999).

There are variations not only in how people perceive environmental problems but also in what are believed to be appropriate resource management practices. Until recently, certain indigenous practices (e.g., the use of certain crop varieties in peasant farming systems) used to be regarded as backward. It has now turned out that some of these practices are quite sustainable and efficient in the agroecological and socio-economic settings in which they are found. Participation in project design and implementation is desirable not only to judge the views of resource users about a particular problem and how it should be addressed, but also to engage them as activists. Unfortunately, however, this empowering aspect of participation is quite often overlooked by project planners.

Social relations involve not only workers or groups at the local level, but also their interactions with institutions at national and international levels. Macroeconomic policies, market trends, political elites, and national bureaucracies influence what happens at the local level, often severely constraining what can be achieved (Anonymous, 1999).

References

Achanta, A. N., Mittal, M., and Mathur, R., The use of economic instruments in carbon dioxide mitigation: a developing country perspective, *Environment and Trade*, **12**: 1–99 (1995).

Alexandratos, N., World food and agriculture: outlook for the medium and longer term, *Proc. Natl. Acad. Sci.* (USA), **96**: 5908–5914 (1999).

Anand, A. S. and Aruna Kumara, V. K., Experimenting with ancient knowledge, *Compas Newsletter* (Leusden), Issue No. 1, p. 23 (1999).

Anonymous, *Development Environment and People, Report of the Conference on the Social Dimensions of Environment and Sustainable Development*, United Nations Research Institute for Social Development (UNRISD), Geneva (1992).

Anonymous, Rural Development, No. 15, pp. 12–13 (1994).

Anonymous, *Status Paper on Indian Railways: Some issues and options*, Government of India, Ministry of Railways, New Delhi (1998).

Anonymous, Promoting people-centred sustainable development, *UNRISD News*, **20**: 14–16 (1999).

Anonymous, Turning the paddy gold: corn in the Southeast Asia, *Seedling (GRAIN) Newsletter*, Issue No. 16, pp. 11–16 (1999a).

Arrow, K., Cropper, M. L., Eads, G. C., Hahn, R. W., Lave, L. B., Noll, R. G., Portney, P. R., Russell, M., Schmalensee, R., Smith, V. K., and Stavins, R. N., Is there a role for benefit-cost analysis in environmental health and safety regulation?, *Science*, **272**: 221–222 (1996).

Barnett, V., Payne, R., and Steiner, R., *Agricultural Sustainability. In Economic, Environmental, and Statistical Considerations*, pp. 63–84, Wiley, London (1995).

Barrow, J. D. and Tipler, F. J., *The Anthropic Cosmological Principle*, Clarendon Press, Oxford (1986).

Baudot, J., Follow-up to the social summit and the spirit of the time, *UNRISD News*, **20**: 1–3 (1999).

Beall, C. M., Optimal birth weights in Peruvian populations at high and low altitudes, *Am. J. Phys. Anthropol.*, **56**: 209–216 (1981).

Becker, K. and Focken, U., Resource utilisation by aquaculture in the tropics requirements of different production systems on the operational resources of fish farmers, *Animal Res. Develop.*, **48**: 84–91 (1998).

Berkes, F., *Common Property Resources: Ecology and community-based sustainable development*, Belhaven Press, London (1989).

Berry, B. J. L., Urbanization. *In* Meyer, W. B. and Turner, B. L., II (eds.) *Changes in Land Use and Land Cover: A global perspective*, pp. 103–120, Cambridge University Press, Cambridge (1990).

Bongaarts, J., Demographic consequences of declining fertility, *Science*, **282**: 419–420 (1998).

Borgstrom, G., *Harvesting the Earth*, Abelard-Schumann, New York (1973).

Boyden, S., *Western Civilization in Biological Perspective: Patterns in biohistory*, Oxford University Press, Oxford (1987).

Brash, D. N., *Sustainable Management and the Environmental Bottom Line*, New Zealand Ministry of the Environment, Wellington (1992).

Braun, M., Fricke, W., and Malchau, G., Functional change of periodic markets in density populated areas in South-East Nigeria, *Applied Geography and Develop.*, **52**: 27–40 (1998).

Bronner, F. (ed.), *Nutrition and Health*, CRC Press, Boca Raton (1995).

Brookfield, H. C. and Paddoch, C., Appreciating agrodiversity: a look at the dynamism and diversity of indigenous farming practices, *Environment*, **38**: 7–11 (1994).

Brown, L. R., *State of the World: A Worldwatch Institute Report on Progress Toward a Sustainable Society*, Norton, New York (1998).

Bruce, J. P., *Meteorology and Hydrology for Sustainable Development*, World Meteorological Organization, WMO No. 769, Geneva (1992).

Burgess, J. C., Timber production, timber trade and tropical deforestation, *Ambio*, **22**: 136–143 (1993).

Calloway, D. H., *Human Nutrition: Food and micronutrient relationships*, International Food Policy Research Institute, Washington, D.C. (1995).

Campbell, D. J. and Olson, J. M., Framework for environment and development: The Kite CASID occasional paper, 10, Center for Advanced Study of International Development, East Lansing, USA (1991).

Cassman, K. G., Ecological intensification of cereal production systems: yield potential, soil quality, and precision agriculture, *Proc. Natl. Acad. Sci.* (USA), **96**: 5952–5959 (1999).

Caughley, G., *Analysis of Vertebrate Populations*, Wiley, New York (1977).

Cesario, M., Contribution of conservation to sustainable living through health promotion, *Ambio*, **25**: 39–43 (1996).

Chameides, P. S. K., Yienger, J., and Levy, H., II, Growth of continental-scale metro-agro-plexes: regional ozone pollution, and world food production. *Science*, **264**: 71–77 (1994).

Chertow, R. and Esty, D. C. (eds.), *Thinking Ecologically: The next generation of environmental policy*, Yale University Press, New Haven, Connecticut (1997).

CIMMYT (International Wheat and Maize Improvement Centre) World Maize Facts and Trends 1997/98, Mexico City (1999).

Cires, R. R., Earthquakes and urban growth, *Nature*, **336**: 625–626 (1988).

Clark, C., The economics of overexploitation, *Science*, **181**: 630–634 (1973).

Clark, J. R., FAO Fisheries Technical Paper 327, Food and Agriculture Organization, United Nations, Rome (1992).

Clark, W. C. and Munn, R. E. (eds.), *Sustainable Development of the Bio-*

sphere, Cambridge University Press, Cambridge (1986).

Coates, J., Where will technology take us?, *Science*, **282**: 15–16 (1998).

Commission of the European Communities, Summary Report of the Seminar on European Strategy for Energy Research and Technological Development: 18–20 November 1993: Held at FONDAZIONE GIORAGIO CINI, ISOLA DI SAN GIORAGIO MAGGIORE, VENICE (1993).

Conway, G., *The Doubly Green Revolution: Food for All in the 21st Century*, pp. 4–5 and 44–65, Cornell University Press, Ithaca, New York (1998).

Costanza, R. (ed.), *Ecological Economics: The science and management of sustainability*, Columbia University Press, New York (1991).

Costanza, R., Arge, R. D., De Groot, R. S., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R. V., Paruelo, J., Raskin, R. G., Sutton, P., and van den Belt, M., The value of the world's ecosystem services and natural capital, *Nature*, **387**: 253–260 (1997).

Costanza, R., Arge, R. D., De Groot, R. S., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R. V., Paruelo, J., Raskin, R. G., Sutton, P., and van den Belt, M., Costanza and his coauthors reply, *Environment*, **40(2)**: 26–28 (1998).

Cronk, L., Human behavioral ecology, *Annu. Rev. Anthropol.*, **20**: 25–53 (1991).

Crook, J. and Crook, S., *Explaining Tibetan Polyandry: Socio-cultural, demographic and biological perspectives*, University of Bristol, Bristol (1994).

Crook, J. and Osmaston, H. (eds.), *Himalayan Buddhist Villages: Environment, resources, society, and religious life*, University of Bristol, Bristol (1994).

Crosby, A. W., *Ecological Imperialism: The biological expansion of Europe, 900–1900*, Cambridge University Press, Cambridge (1986).

Crumley, C. L., Historical ecology: finding common ground, *Human Dimensions*, **1(3)**: 6–8 (1995).

Cummings, B., *Dam the Rivers—Damn the People: Development and resistance in Amazonian Brazil*, Earthscan Publications, London (1990).

Daily, G. C. (ed.), *Nature's Services: Society's dependence on natural ecosystems*, Island Press, Washington, D.C. (1997).

Daily, G. C., Ehrlich, A. H., and Ehrlich, P. R., Socioeconomic equity: a critical element in sustainability, *Ambio*, **24**: 58–59 (1995).

Daly, H. E., Elements of environmental macroeconomics. *In* Costanza, R. (ed.) *Ecological Economics: The science and management of sustainability*, p. 32, Columbia University Press, New York (1991).

Davidson, A. and Weekley, K. (eds.), *Globalization and Citizenship in the Asia-Pacific Region*, Macmillan, London (1999).

De Groot, R. S., *Evaluation of Nature in Environment Planning Manage-*

ment and Decision Making, Walters-Noordhoff, Amsterdam (1992).

Delgado, C., Crosson, P., and Courbois, C., The impact of livestock and fisheries on food availability and demand in 2020, *J. Internat. Food Policy Res. Inst.* (IFPRI), 1–12 (1995).

DellaPenna, D., Nutritional genomics: manipulating plant micronutrients to improve human health, *Science*, 285: 375–379 (1999).

Der-Petrossian, B., Conflicts between the construction industry and the environment, *UNCHS (Habitat)*, 5(2): 7–9 (1999).

DeSteiger, J. E., *The Age of Environmentalism*, McGraw-Hill, New York (1997).

Diegues, A. C., *Regional and Domestic Mass Tourism in Brazil: An overview*, mimeograph (October 1997) (unpublished).

Dietz, H. M., *Conference Proceedings, Small-scale Food Processing Contributing to Food Security*, Deutsche Stiftung für International Entwicklung, Bonn (1995).

Dimson, B., Principles and challenges of sustainable design and construction, *Industry and Environment*, 19(2): 19, UNEP/IE (1996).

Döös, B. R., Environmental degradation, global food production, and risk for large-scale migrations, *Ambio*, 22: 124–129 (1993).

Dumont, L., *Homo Hierarchicus: The caste system and its implications*, University of Chicago Press, Chicago (1980).

ECE/UNEP, Guidelines on Integrated Environmental Management in Countries in Transition, ECE/UNEP/FP/2101-92-02 (3002), United Nations, New York (1994).

Faiz, A., Weaver, C. S., and Walsh, M. P., *Air Pollution from Motor Vehicles*, World Bank, Washington, D.C. (1996).

Falkenmark, M., A holistic approach to water quality management, *Ambio*, 22: 53 (1993).

FAO (Food and Agriculture Organization), *Production Yearbook*, United Nations, Rome (1991).

FAO (Food and Agriculture Organization), *Report of the Expert Consultation on Utilization and Conservation of Aquatic Genetic Resources*, Grottaferrata, Italy, 9–13 November 1992, FAO Fisheries Report No. 491, FAO Fisheries Department, United Nations, Rome (1992).

FAO (Food and Agriculture Organization), Agriculture: Towards 2010, United Nations, Rome (1993).

FAO (Food and Agriculture Organization), *Marine Fisheries and the Law of the Sea: A Decade of Change*, Special chapter (revised) of The State of Food and Agriculture 1992, FAO Fisheries Circular No. 853, FAO Fisheries Department, United Nations, Rome (1993a).

FAO (Food and Agriculture Organization), *Development Education Exchange Papers*, United Nations, Rome (1995).

FAO (Food and Agriculture Organization), *Food for Consumers*, United

Nations, Rome (1995a).

FAO (Food and Agriculture Organization), *Dimensions of Need: An atlas of food and agriculture*, United Nations, Rome (1995b).

FAO (Food and Agriculture Organization), *Agricultural Production Data, Updated in June 1999*, United Nations, Rome (1999).

Fedoroff, N. V. and Cohen, J. E., Plants and population: is there time?, *Proc. Natl. Acad. Sci.* (USA), **96**: 5903–5907 (1999).

Fehr, M., An integrated environmental matrix for a social unit, *Resources, Conservation and Recycling*, **22**: 193–202 (1998).

Fereday, A., Gibson, N. R., Cox, M., Pacy, P. J., and Millward, D. J., Protein requirements and ageing: metabolic demand and efficiency of utilization, *Brit. J. Nutrition*, **77**: 685–702 (1997).

Fettweis, G. B. L., On the economic principle in mining particularities and integration into the superordinate rational principle, *Natural Resources and Development*, **42**: 92–111 (1995).

Flaherty, M. and Rappaport, A., Corporate environmentalism: from rhetoric to results, *UNRISD News*, **17**: 4–6 (1997).

Flores, E. O., Human settlements, environment and quality of life, *The Network*, p. 2 (April 1994).

Folke, C., Perrings, C., McNeely, J. A., and Myers, N., Biodiversity conservation with a human face: ecology, economics and policy, *Ambio*, **22**: 62–63 (1993).

Food and Nutrition Board, National Research Council (U.S.), *Recommended Dietary Allowances*, 10th edn., National Academy Press, Washington, D.C. (1989).

Forteath, N., Aquaculture: the new wave, *Search*, **28**: 25–28 (1997).

Fullerton, D. and Stavins, M., How economists see the environment?, *Nature*, **395**: 433–434 (1998).

Gadgil, M., Social restraints on resource utilization: the Indian experience. *In* McNeely, J. A. and Pitt, D. (eds.) *Culture and Conservation: The human dimension in environmental planning*, pp. 135–154, Croom Helm, London (1985).

Gadgil, M., Ecological organization of the Indian Society (Vikram Sarabhai Memorial Lecture, 13 Feb., 1991, ICSSR), *ICSSR Newsletter*, Issue No. 21, pp. 1–9 (1991).

Gadgil, M. and Guha, R., *The Fissured Land: An ecological history of India*, University of California Press, Berkeley (1992).

Gadgil, M. and Thapar, R., Human ecology in India: some historical perspectives, *Interdiscip. Sci. Rev.*, **15**: 209–223 (1990).

Gaia Foundation and GRAIN (Genetic Resources Action International), *Global Trade and Biodiversity in Conflict*, Issue No. 3, *Intellectual Property Rights and Biodiversity: The Economic Myths*, London and Barcelona (1998).

Gardner, J. E., The elephant and the nine blind men: an initial review of environmental assessment and related processes in support of sustainable development. *In* Jacobs, P. and Sadler, B. (eds.) *Sustainable Development and Environmental Assessment: Perspectives on planning for a common future*, pp. 35–66, CEARC, Hull, Quebec (1991).

Gelbspan, R., *The Heat is On: The high stakes battle over earth's threatened climate*, Addison-Wesley, New York (1997).

Georgescu-Roegen, N., Energy and economic myths, *South Economic Jour.*, **41**: 347–381 (1975).

Georgescu-Roegen, N., The steady state and ecological salvation: a thermodynamic analysis, *BioScience*, **27**: 266–270 (1977).

Ghimire, M., Tharu farmers relate soil and soul, *Compas Newsletter* (Leusden), Issue No. 1, pp. 10–11 (1999).

Ghosh, J., *Assessing Poverty Alleviation Strategies for their Impact on Poor Women: A study with special reference to India*, United Nations Research Institute for Social Development (UNRISD), Discussion Paper No. 97, Geneva (1998).

Goldstein, M. C., New perspectives on Tibetan fertility and population decline, *American Ethnologist*, **8**: 721–738 (1981).

Gonese, C., The three worlds, *Compas Newsletter* (Leusden), Issue No. 1, pp. 20–22 (1999).

Goodwin, C. N., Hawkins, C. P., and Kershner, J. L., Riparian restoration in the western United States: overview and perspective, *Restoration Ecol.*, **5**: 4–14 (1997).

Goudsblom, J. and Aarts, W., The trickle-down effect and the environment problem, *Change*, **18**: 12–13 (1994).

Gowtham Shankar, K. J. N., Culture and agro-ecology in tribal areas, *Compas Newsletter* (Leusden), Issue No. 1, pp. 34–35 (1999).

Graedel, T. E. and Crutzen, P. J., The changing atmosphere, *Sci. Amer.*, **261**: 28–37 (1989).

Gregory, S. V., Swanson, F. J., McKee, W. A., and Cummins, K. W., An ecosystem perspective of riparian zones, *BioScience*, **41**: 540–551 (1991).

Gupta, M. V., Rahman, M. A., Mazid, M. A., and Sollows, J. D., Integrated agriculture-aquaculture: a way for food security for small farmers and better resource management and environment. *In* Heidhues, F. and Fadani, A. (eds.) *Food Security and Innovations*, pp. 165–175, Peter Lang, Eur. Verlag der Wissenschaften, Frankfurt (1997).

Hammond, A. (1999), *Which World?: Scenarios for the 21st century*, Island Press, Washington, D.C. (1998).

Hanneberg, P., Sustainable development must be defined locally, *Enviro. Newsletter*, Issue No. 14, pp. 18–21 (1992).

Harris, J. M., *World Agriculture and the Environment*, Garland, New York (1990).

Hawkes, K., O'Connel, J. F., and Rogers, L., The behavioral ecology of modern hunter-gatherers, and human evolution, *TREE*, **12**: 29–32 (1997).

Hazell, P. B. R., *Agricultural Growth, Poverty Alleviation, and Environmental Sustainability: Having it all*, 2020 Brief No. 59, International Food Policy Research Institute, Washington, D.C. (1999).

Hecht, S. and Cockburn, A., *The Fate of the Forest: Developers, destroyers and defenders of the Amazon*, Penguin, London (1990).

Herdt, R. W. Assisting developing countries toward food self-reliance, *Proc. Natl. Acad. Sci.* (USA), **95**: 1989–1992 (1998).

Hoffmann, I., Wetstein, C., and Schäfer, C., Description of a grazing ecosystem in north-western Nigeria using environmental indicators, *Animal Res. Develop.*, **48**: 69–83 (1998).

Holdren, J., Population and the energy problem, *Population Environ.*, **12**: 231–255 (1991).

Holdren, J., The transition to costlier energy. *In* Schipper, L. and Meyers, S. (eds.) *Energy Transitions*, Stockholm Environmental Institute, Stockholm (1992).

Holligan, P. M. and DeBoois, H., *Land-Ocean Interactions in the Coastal Zone (LOICZ)*, IGBP Report No. 25, International Geosphere-Biosphere Programme, Stockholm (1993).

Hook, W., Making urban transport sustainable, *Gate Newsletter*, Issue No. 3, pp. 8–14 (1998).

Houghton, R. A. and Skole, D. L., Carbon. *In* Meyer, W. B. and Turner, B. L., II (eds.) *Changes in Land Use and Land Cover: A global perspective*, pp. 393–408, Cambridge University Press, Cambridge (1990).

Howarth, R. W., Nutrient limitation of net primary production in marine ecosystems, *Annu. Rev. Ecol.*, **19**: 89–110 (1988).

Hupp, C. R., Riparian vegetation recovery patterns following stream channelization: a geomorphic perspective, *Ecology*, **73**: 1209–1226 (1992).

IDRC (International Development Research Centre), The global research agenda: a south-north perspective, *Interdiscip. Sci. Rev.*, **16**: 343–344 (1991).

IFPRI (International Food Policy Research Institute), *A 2020 Vision for Food, Agriculture and the Environment: The vision, challenges and recommended action*, Washington, D.C. (1995).

Ingco, M., Mitchell, D., and McCalla, A., *Global Food Supply Prospects*, Technical Paper No. 353, World Bank, Washington, D.C. (1996).

IPCC (Intergovernmental Panel on Climate Change), *The IPCC Supplement: Scientific assessment*, Cambridge University Press, Cambridge (1990).

IPCC (Intergovernmental Panel on Climate Change), Climate Change:

Policy Instruments and their implications. *In* Proceedings Tsukuba Workshop of IPCC Working Group III, Tsukuba, Japan, January 17–20 (1994).

Jackson, C. and Palmer-Jones, R., *Work Intensity, Gender and Well-being*, United Nations Research Institute for Social Development (UNRISD), Discussion Paper No. 96, Geneva (1998).

Jacobs, P. and Munro, D. A. (eds.), *Conservation with Equity: Strategies for sustainable development*, Cambridge University Press, Cambridge (1988).

Jacobs, P. and Sadler, B. (eds.), *Sustainable Development and Environmental Assessment: Perspectives on planning for a common future*, Canad. Environ. Assess. Res. Council, Hull, Quebec (1991).

Jäger, J., The human side of global change, *Environment*, **40**: 25–26 (1998).

Jazairy, I., Alamgir, M., and Panuccio, T., *The State of the World Rural Poverty: An equiry into its causes and consequences*, IFAD/New York University Press, New York (1992).

Jevons, W., *The Theory of Political Economy*, 2nd edn., Macmillan, London (1979).

Johnson, D. G., The growth of demand will limit output growth for food over the next quarter century, *Proc. Natl. Acad. Sci.* (USA), **96**: 5915–5920 (1999).

Jones, I. S. F., Enhanced carbon dioxide uptake by the world's oceans, *Energy Conversion and Management*, **37**: 1049–1052 (1996).

Jones, J. A. A., *Global Hydrology: Processes, resources and environmental management*, Addison-Wesley Longman, Harlow, Essex (1997).

Kajale, M. D., Plant economy. *In* Dhavalikar, M. K., Sankhalia, H. D., and Ansari, Z. D. (eds.) *Excavations at Inamgaon*, Vol. 1, Part ii, pp. 727–821, Deccan College, Pune (1988).

Kates, R. W., The interactions of climate and society. *In* Kates, R. W., Ausubel, J. H., and Berberian, M. (eds.) *Climate Impact Assessment: Studies of the interaction of climate and society* (SCOPE 27), pp. 3–36, Wiley, Chichester (1985).

Kaufmann, J. B., Beschta, R. L., Otting, N., and Lytjen, D., An ecological perspective of riparian and stream restoration in the western United States, *Fisheries*, **22**: 12–24 (1997).

Kelly, R. L., *The Foraging Spectrum: Diversity in hunter-gatherer lifeways*, Smithsonian Institution Press, Washington, D.C. (1995).

Kendall, H. *et al.*, Bioengineering of crops. *In* Serageldin, I. and Collins, W. (eds.) *Biotechnology and Biosafety*, pp. 1–214, Proceedings of a Workshop, Environmentally and Socially Sustainable Development Series, World Bank, Washington, D.C. (1999).

Kentula, M. E., A step toward a landscape approach in riparian restoration, *Restoration Ecol.*, **5**: 2–3 (1997).

Kieft, J., Farmers' decisions and cosmovision, *Compas Newsletter* (Leusden), Issue No. 1, pp. 18–19 (1999).

Kishore, G. M. and Shewmaker, C., Biotechnology: enhancing human nutrition in developing and developed worlds, *Proc. Natl. Acad. Sci.* (USA), **96**: 5968–5972 (1999).

Kumar, H. D., *Modern Concepts of Ecology*, 8th edn., Vikas, New Delhi (1995).

Kumar, H. D., *A Textbook on Biotechnology*, East-West Press, New Delhi (1998).

Kumar, H. D., *Biodiversity and Sustainable Conservation*, Oxford and IBH, New Delhi (1999).

Kumar, H. D. and Häder, D. P., *Global Aquatic and Atmospheric Environment*, Springer-Verlag, Berlin/Heidelberg (1999).

Kumar, H. D. and Kumar, S., *Global and General Environment*, Anmol Publishers, New Delhi (1997).

Latham, M. C., *Human Nutrition in the Developing World*, FAO Food and Nutrition Series 29, Food and Agriculture Organization, United Nations, Rome (1997).

Leisinger, K. M., Sociopolitical effects of new biotechnologies in developing countries, Discussion Paper No. 2, International Food Policy Research Institute., Washington, D.C. (1995).

Lenssen, N. and Roodman, D. M., *State of World: Making better buildings*, Worldwatch Institute, London (1995).

Lohmeyer, U., Integrated coastal management: a new mega-term or a concept for the sustainable utilization of coastal regions?, *Animal Res. Develop.*, **48**: 58–68 (1998).

Long, B. L., Cleaner production in OECD countries, *Industry and Environment*, **17**: 23 (1995).

Lugo, A. E., Parrotta, J. A., and Brown, S., Reduction of species due to tropical deforestation and their recovery through management, *Ambio*, **22**: 106–109 (1993).

Maguire, D. J., Goodchild, M. F., and Rhind, D. W., *Geographical Information Systems: Principles and applications*, Vols. 1 & 2, Longman, London (1991).

Martin, C., *Keepers of the Game: Indian-animal relationship and the fur trade*, University of California Press, Berkeley (1978).

Masood, E. and Garwin, L., Costing the earth: when ecology meets economics, *Nature*, **395**: 426–429 (1998).

Max-Neef, M., Elizalde, A., and Hopenhayn, M., Human scale development: an option for the future, *Develop. Dialogue* (Uppsala), 5–39 (1989).

Maybeck, M., Chapman, D. V., and Helmer, R., *Global Freshwater Quality: A first assessment*, WHO/UNEP Publication, Geneva (1989).

McNeely, J. A., How dams and wildlife can co-exist: natural habitat, agriculture and major water resource development projects in tropical Asia, *Conserv. Biol.*, **1(3)**: 227–239 (1987).

McNeely, J. A., Environmental assessment in support of sustainable development. *In* Jacobs, P. and Sadler, B. (eds.) *Sustainable Development and Environmental Assessment: Perspectives on planning for a common future*, pp. 105–114, Canad. Environ. Assess. Res. Council, Hull, Quebec (1991).

McNeely, J. A. and Pitt, D. (eds.), *Culture and Conservation: The human dimension in environmental planning*, Croom Helm, London (1985).

Meadows, D. H., Meadows, D. L., Randers, J., and Behrens, W. W., *The Limits to Growth*, Universe Books, New York (1972).

Meredith, H. V., Body weight at birth of viable human infants: a worldwide comparative treatise, *Hum. Biol.*, **42**: 217–264 (1970).

Messerli, B. P., Wirtschaftliche Entwicklung und Ökologische Belastoarkeit in Berggebiet (MAB Schweiz), *Geogr. Helvetica*, **33**: S203–210 (1978).

Meyer, W. B. and Turner, B. L., II, *Changes in Land Use and Land Cover: A global perspective*, Cambridge University Press, Cambridge (1994).

Ministry of Finance, The India Infrastructure Report, Government of India, New Delhi (1996).

Mlot, C., Plant biology in the genome era, *Science*, **281**: 331–332 (1998).

Moore, L. G., Maternal O_2 transport and fetal growth in Colorado, Peru, and Tibet high altitude residents, *Am. J. Hum. Biol.*, **2**: 627–637 (1990).

Muir, G., Regier, H. A., and Williams, T. H., The Great Lakes, *Seasons*, **27**: 3–10 (1987).

Myers, N., Everyday extinctions in embattled forests, *Nature*, **400**: 231–232 (1999).

Nanjundaiah, M. S., Energy and environmental issues in transport, *Current Science*, **75**: 804–811 (1998).

Nanson, G. C. and Croke, J. C., A genetic classification of floodplains, *Geomorphology*, **4**: 459–486 (1992).

Naveh, Z., The value of open landscapes as life-supporting systems, *Israel Environ. Bull.*, **20(4)**: 21–24 (1997).

Naveh, Z. and Lieberman, A., *Landscape Ecology, Theory and Application*, Springer-Verlag, New York (1994).

Newbury, R., Rivers and the art of stream restoration. *In* Costa, J. E., Miller, A. J., Potter, K. W., and Wilcock, P. R. (eds.) *Natural and Anthropogenic Influences in Fluvial Geomorphology*, Geophysical Monograph 89, pp. 137–149, American Geophysical Union, Washington, D.C. (1995).

Newton, P., A manual for planetary management, *Nature*, **400**: 399 (1999).

Norberg-Hodge, H., Ladakh: development without destruction. *In* Lall,

J. S. (ed.) *The Himalaya: Aspects of change*, Oxford University Press, New Delhi (1981).

Norberg-Hodge, H., *Ancient Futures: Learning from Ladakh*, Sierra Club Books, San Francisco (1991).

Norboo, T. and Yahya, M., Health problems in Ladakh, *Voice of the Himalaya*, 1: 5–9 (1988).

Norboo, T., Yahya, M., Bruce, N. G., Heady, J. A., and Ball, K. P., Domestic pollution and respiratory illness in a Himalayan village, *Int. J. Epidemiol.*, 20: 749–757 (1991).

Norgaard, R. B., The case for methodological pluralism, *Ecol. Econ.*, 1: 37–57 (1989).

Norgaard, R. B., *Development Betrayed: The end of progress and a coevolutionary vision of the future*, Routledge, London (1994).

Norton, J., Sustainable architecture: a definition, *UNCHS (Habitat)*, 5(2): 10–11 (1999).

Noss, R. F. and Cooperrider, A. Y., *Saving Nature's Legacy*, Island Press, Washington, D.C. (1994).

NRC (National Research Council), *A Common Journey: Toward a sustainability transition*, National Academy Press, Washington, D.C. (1999).

Odada, E., Totolo, O., and Smith, M. S., Global Change and Subsistence Rangelands in Southern Africa, GCTE Working Document No. 20 (1996).

OECD (Organization for Economic Cooperation and Development), *Environmental Policy: How to apply economic instruments?*, Paris (1991).

OECD (Organization for Economic Cooperation and Development), *The Economic Costs of Reducing* CO$_2$ *Emissions*, OECD Economic Studies, No. 19/Winter 1992, Paris (1993).

OECD (Organization for Economic Cooperation and Development), *Indicators for the Integration of Environmental Concerns into Energy Policies*, OECD Environment Monograph, No. 79, Paris (1993a).

OECD (Organization for Economic Cooperation and Development), *OECD core set of indicators for the environmental performance reviews*, OECD Environment Monograph, No. 83, Paris (1993b).

OECD (Organization for Economic Cooperation and Development), *Economic Instruments for Environmental Management in Developing Countries*, Paris (1993c).

OECD (Organization for Economic Cooperation and Development), *Trade and Environment: Environmental subsidies*, Document OECD/GD (95) 16, Paris (1995).

OECD (Organization for Economic Cooperation and Development), *Integrating Environment and Economy: Progress in the 1990s*, Paris (1996).

OECD (Organization for Economic Cooperation and Development), *Implementation Strategies of Environmental Taxes*, Paris (1996a).

Olson, C. and Harris, R., Applying a two-stage system to prioritize riparian restoration at the San Luis Rey River, San Diego Country, California, *Restoration Ecol.*, 5: 43–55 (1997).

O'Neill, M. P., Schmidt, J. C., Dobrowolski, J. P., Hawkins, C. P., and Neale, C. M. U., Identifying sites for riparian wetland restoration: application of a model to the Upper Arkansan River basin, *Restoration Ecol.*, 5: 85–102 (1997).

Opitz, S., Sustainable mobility and rural transport, *Gate Newsletter*, Issue No. 3, pp. 39–42 (1998).

O'Riordan, T., Globalism and localism, *Environment*, **40**: 24 (1998).

Osmaston, H., The farming system. *In* Crook, J. and Osmaston, H. (eds.) *Himalayan Buddhist Villages: Environment, resources, society, and religious life,* University of Bristol, Bristol (1994).

Padam, S., Transport needs regulation, *Current Science*, **75**: 790–794 (1998).

Parry, M., Arnell, N., Hulme, M., Nicholls, R., and Livermore, M., Adapting to the inevitable, *Nature*, **395**: 741 (1998).

Pearce, D., *Blueprint 4: Capturing global environment value*, Earthscan Publications, London (1995).

Pearce, D., Auditing the earth, *Environment*, **40(2)**: 23–28 (1998).

Perrings, C., *Economy and Environment: A theoretical essay on the interdependence of economic and environmental systems*, Cambridge University Press, Cambridge (1995).

Perrings, C., Economic values of biodiversity. *In* Heywood, V. H. (ed.) *Global Biodiversity Assessment*, pp. 823–914, Cambridge University Press, Cambridge (1995a).

Perrings, C., Folke, C., and Maler, K. G., The ecology and economics of biodiversity loss, *Ambio*, **21**: 201–211 (1992).

Pingali, P. L., Hossain, M., and Gerpacio, R. V., *Asian Rice Bowls: The returning crisis?*, CAB International, Wallingford (1997).

Platt, D. D., Irland, L. C., and Conkling, P. W., Towards a definition of sustainability, *Human Dimensions*, **1(4)**: 18–20 (1996).

Population Reference Bureau, *1998 World Population Data Sheet*, Washington, D.C. (1998).

Possehl, G. L. (ed.), *Harappan Civilization*, Oxford and IBH, New Delhi (1982).

Prat, A. R. M., Fishing out aquatic diversity, *Seedling (GRAIN) Newsletter*, Issue No. 12, pp. 2–13 (1995).

Pushpangadan, P., *Ethnobiology in India: A status report*, Ministry of Environment and Forests, Government of India, New Delhi (1995).

RAFI (Rural Advancement Foundation International), The Gene Giants: Masters of the Universe?, *RAFI Communique*, Osborne, Winnipeg (1999).

Raman, V. and Anantharamaiah, K. M., Transport policy issues, *Current Science,* 75: 778–784 (1998).

Ramprasad, V., Prasad, K., and Gopinath, G., Strengthening our cultural heritage, *Compas Newsletter* (Leusden), Issue No. 1, p. 12 (1999).

Rao, Nina and Suresh, K. T., Domestic Tourism Policies in India, mimeograph (October 1997) (unpublished).

Raskin, P., Chadwick, M., Jackson, T., and Leach, G., *The Sustainability Transition: Beyond conventional development*, Stockholm Environmental Institute, Stockholm (1996).

Raskin, P., Gallopin, G., Gutman, P., Hammond, A., and Swart, R., *Bending the Curve: Toward global sustainability*, Stockholm Environmental Institute, Stockholm (1998).

Razavi, S., *Gendered Poverty and Social Change: An issues paper,* United Nations Research Institute for Social Development (UNRISD), Discussion Paper No. 94, Geneva (1998).

Rees, W., A role for environmental assessment in achieving sustainable development, *Environ. Impact Assess. Rev.*, 8: 273–291 (1988).

Rees, W., Econonics, ecology and the role of environmental assessment in achieving sustainable development. *In* Jacobs, P. and Sadler, B. (eds.) *Sustainable Development and Environmental Assessment: Perspectives on planning for a common future*, pp. 123–142, Canad. Environ. Assess. Res. Council, Hull, Quebec (1991).

Regier, H. A., A focus on reform and on redevelopment of degraded regions. *In* Jacobs, P. and Sadler, B. (eds.) *Sustainable Development and Environmental Assessment: Perspectives on planning for a common future,* pp. 67–79, Canad. Environ. Assess. Res. Council, Hull, Quebec (1991).

Relf, C., Obvious, but not easy, *Gate Newsletter*, Issue No. 3, pp. 20–23 (1998).

Repetto, R., *Jobs, Competitiveness, and Environmental Regulation: What are the real issues?*, World Resources Institute, Washington, D.C. (1994).

Rifkin, J., *The Biotech Century,* Tarcher/Putnam, New York (1998).

Rizvi, J., *Ladakh: Crossroads of high Asia,* Oxford University Press, New Delhi (1983).

Rosegrant, M. W., Leach, N., and Gerpacio, R. V., *Alternative Futures for World Cereal and Meat Consumption,* International Food Policy Research Institute, Washington, D.C. (1998).

Rosenzweig, C. and Hittel, D., *Climate Change and the Global Harvest,* Oxford University Press, New York (1998).

Rotmans, J. and Dowlatabadi, H., Human choice and climate change. *In* Rayner, S. and Malone, E. L. (eds.) *The Tools for Policy Analysis,* Batelle, Columbus, 291–377 (1998).

Rudel, T. K., Population, development, and tropical deforestation: a cross-national study, *Rural Sociology*, **54**: 327–338 (1989).

Ruttan, V. (ed.), *Agriculture, Environment and Health: Towards sustainable development into the 21st century,* University of Minnesota Press, Minneapolis (1994).

Ruttan, V. W., The transition to agricultural sustainability, *Proc. Natl. Acad. Sci.* (USA), **96**: 5960–5967 (1999).

Saith, R. and Harriss-White, B., *Gender Sensitivity of Well-being Indicators,* United Nations Research Institute for Social Development (UNRISD), Discussion Paper No. 95, Geneva (1998).

Sambraus, H. H., Befindlichkeiten und Analogieschluß, *Akt. Arb. Artgem., Tierhaltung*, **370**: 31–39 (1994).

Sankhala, K. S. and Jackson, P., People, trees and antelopes in the Indian desert. *In* McNeely, J. A. and Pitt, D. (eds.) *Culture and Conservation: The human dimension in environmental planning,* Croom Helm, London (1985).

Schellnhuber, H. J. and Wenzel, V. (eds.), *Earth System Analysis: Integrating science for sustainability,* Springer-Verlag, Berlin (1998).

Schulze, E. D. and Mooney, H. A., *Biodiversity and Ecosystem Function,* Springer-Verlag, New York (1993).

Scura, L. F., Thia-Eng, C., Pido, M., and Paw, J., Lessons for integrated coastal zone management, *ASEAN Experience*, 1–70 (1992).

Serageldin, I., Biotechnology and the food security in the 21st century, *Science,* **285**: 387–389 (1999).

Sieber, N., No easy walk to wealth, *Gate Newsletter*, Issue No. 3, pp. 15-19 (1998).

Sieber, N. and Kipke, B. G., Mobility for the majority, *Gate Newsletter*, Issue No. 3, pp. 4–7 (1998).

Sivakumar, M. V. K., Climate variability and food vulnerability, *Global Change Newsletter*, No. **35**, pp. 15–17 (1998).

Smith, C. F., Comparative birth weight data for Sherpa women living at high and low altitudes in Nepal, *Am. J. Phys. Anthropol.*, **91**: 183 (Abstract) (1993).

Smith, D. K., *Natural Disaster Reduction: How meteorological and hydrological services can help,* World Meteorological Organization, WMO No. 722, Geneva (1989).

Smith, J. M. and Szathmary, E., On the likelihood of habitable worlds, *Nature,* **384**: 107 (1996).

Smith, P. J., *Genetic Diversity of Marine Fisheries Resources: Possible impacts of fishing*, FAO Fisheries Technical Paper 344, Food and Agriculture Organization, United Nations, Rome (1995).

Solow, R., The economics of resources or the resources of economics?, *Amer. Economic Rev.*, **64**: 1–14 (1974).

Somanathan, E., Deforestation, property rights and incentives in central Himalaya, *Economic and Political Weekly*, **26**: PE 37–PE 46 (1991).

Southgate, D. and Clark, H. L., Can conservation projects save biodiversity in South America?, *Ambio*, **22**: 163–166 (1993).

Sriraman, S., Road transport development in India, *Current Science*, **75**: 785–789 (1998).

Stobdan, P., Ecology of disease in Ladakh. *In* Icke-Schwalbe, L. and Meier, G. (eds.) *Wissenschaftgeschichte und Gegenwartige Forschungen in Nordwest-Indien*, Staatliches Musem fur Volkerkunde, Dresden Forschungsstelle (1990).

Swaminathan, M. S., Malthus and Mendel: population, science and sustainable food security, *Current Science*, **74**: 203–204 (1998).

Thapar, R., *From Lineage to State*, Oxford University Press, Bombay (1984).

Thomashow, M., *Ecological Identity: Becoming a reflective environmentalist*, MIT Press, Cambridge, Massachusetts (1995).

Turner, B. L., II and Butzer, K. W., The Columbian encounter and land-use change, *Environment*, **43**: 16–20 (1992).

Turner, B. L., II, Skole, D., Sanderson, S., Fischer, G., Fresco, L., and Leemans, R., *Land-use and Land-cover Change: Science/research plan*, IGBP Report No. 35 (HDP Report No. 7), Stockholm and Geneva (1995).

UN (United Nations), *World Population Prospects: The 1996 revision*, New York (1996).

UN (United Nations), *World Population Estimates and Projections, 1998 Briefing Packet*, New York (1998).

UN (United Nations), *World Population Projections to 2150*, New York (1998a).

UNCTAD, *The TRIPs Agreement and Developing Countries*, UNCTAD, Geneva (1997).

UNDP (United Nations Development Programme), *Human Development Report 1998*, p. 19, Oxford University Press, New York (1998).

UNESCO (United Nations Educational, Scientific and Cultural Organization), *Tropical Forest Ecosystems*, Paris (1978).

UNPF (United Nations Population Fund), *Population, Food Production and Nutrition*, New York (1999).

UNRISD (United Nations Research Institute for Social Development), *Report of the International Conference on Globalization and Citizenship*, Geneva (1997).

UNRISD (United Nations Research Institute for Social Development), *Social Development Research*, Geneva (1998).

Upawansa, G. K., The ECO approach to agricultural development, *Compas Newsletter* (Leusden), Issue No. 1, pp. 14–15 (1999).

Utting, P. and Jaubert, R. (eds.), *Discourse and Reality of Participatory Conservation: The case of Senegal* (in French), Institut Unversitaire d'etudes du developpement (IUED), Geneva (1998).

van der Ploeg, J. D., Practices and perspectives in Europe, *Compas Newsletter* (Leusden), Issue No. 1, pp. 24–25 (1999).

Vaughan, S., Introduction. *In* Juma *et al.* (eds.) *Economic Policy Reforms and the Environment: African experience*, pp. 1–7, United Nations Environment Programme, Geneva (1995).

Vester, F., *Ein Baum is Mehr als ein Baun*, Koesel-Verlag, Munchen (1985).

Vijayalakshmi, K., *Traditional Indian Agriculture*, Wiley Eastern, New Delhi (1993).

Vivian, J. M., *Greening at the Grassroots: People's participation in sustainable development*, United Nations Research Institute for Social Development (UNRISD), Discussion Paper No. 22, Geneva (1991).

Vlek, C., Social-behavioural versus technical solutions to global environmental change, *Change Newsletter*, Issue No. 15, pp. 7–9 (1993).

Wahl, S. V., *Investment Appraisal and Economic Evaluation of Mining Enterprise*, Clausthal-Zellerfeld, Paris (1983).

Wattenberg, B., The population explosion is over, *New York Times*, p. 61 (23 November, 1997).

WCED (World Commission on Environment and Development), *Our Common Future*, Oxford University Press, Oxford (1987).

WCFSD (World Commission on Forests and Sustainable Development), *Our Forests, Our Future*, Report of the World Commission on Forests and Sustainable Development, Cambridge University Press, Cambridge (1999).

Welford, R., *Hijacking Environmentalism: Corporate responses to sustainable development*, Earthscan Publications, London (1997).

Welsch, H., Umweltschutz und Wohlfahrtsmessung: Zur Funktion und Bewertung der Umwelt in Wirtschaftsprozess, *Zeit. f. Umweltpolitik*, **3**: 269–298 (1992).

Westman, W. E., *Ecology, Impact Assessment and Environmental Planning*, Wiley, New York (1985).

WHO/FAO, *Food Safety Issues Associated with Products from Aquaculture*, Technical Report No. 883, World Health Organization, Geneva (1999).

Wiley, A. S., Neonatal size and infant mortality at high altitude in the Western Himalaya, *Am. J. Phys. Anthropol.*, **94**: 289–305 (1994).

Wiley, A. S., Neonatal and maternal anthropometric characteristics in a high altitude population of the Western Himalaya, *Am. J. Human Ecol.*, **6**: 499–510 (1994a).

Wiley, A. S., A role for biology in the cultural ecology of Ladakh, *Human Ecology*, **25**: 273–295 (1997).

Wilson, E. O. and Peter, F. M. (eds.), *Biodiversity*, National Academy Press, Washington, D.C. (1988).

WMO (World Meteorological Organization), *Meteorology and the Transfer of Technology*, WMO No. 786, Geneva (1993).

World Bank, *World Development Report 1993*, World Bank, Washington, D.C. (1993).

World Bank, *Implementing the World Bank's Strategy to Reduce Poverty: Progress and challenges*, World Bank, Washington, D.C. (1993a).

World Bank, *World Development Report 1997*, Oxford University Press, New York (1997).

Yip, R., Altitude and birth weight, *Pediatrics*, **111**: 869–876 (1987).

Young, C. (ed.), *Ethnic Diversity and Public Policy: A comparative inquiry*, Macmillan, London (1998).

Zamudio, S., Droma, T., Norkyel, K. Y., Acharya, G., Zamudio, J. A., Niermeye, S. N., and Moore, L. G., Protection from intrauterine growth retardation in Tibetans at high altitude, *Am. J. Phys. Anthropol.*, **91**: 215–224 (1993).

Ziegler, E. E. and Filer, L. J. J. (eds.), *Present Knowledge in Nutrition*, International Life Sciences Institute, Washington, D.C. (1996).

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02225681

SUSTAINABLE HUMAN ECOLOGY

H. D. Kumar

Humans now occupy centre stage in the biosphere. They influence the environment with their activities and are in turn affected by the environment. Every day brings more evidence of how the environment is being changed and how this change has already taken and is taking effect globally. This highlights the need for a sound scientific understanding of the earth system to help human societies develop in ways that sustain the life-support system. An integrated focus is therefore needed on those cross-cutting issues where such an understanding can help this development in the current geological epoch—the so-called *anthroposphere* or *homosphere*—characterized by diverse, major, and lasting impacts of human activities, at local, regional, and global scales.

By contributing to our knowledge and understanding, *Sustainable Human Ecology* enables us to come to terms with the various changes underway on the earth's surface. It analyzes important environmental issues, notably, acid rain, unclean air and water, warming, drought and disasters, in the context of global ecological and economic interdependence and underscores the need for sustainable development. It also calls for radical transformation in our assumptions and habits—particularly by those of us who live in the developed world.

The study is aimed at students of/researchers in anthropology, aquatic biology, botany, ecology, economics, forestry, geography, geology, oceanography, sociology, as well as climatology, demography, limnology, and, above all, at the lay public.

H. D. Kumar was formerly Professor of Botany, Banaras Hindu University, Varanasi. He is the author, among others, of *A Textbook on Biotechnology*, *Forest Resources: Conservation and Management*, and *Plant-Animal Interactions*—all published by East-West Press.

ISBN 81-7671-026-1